1958

Analysis of mining mechanization in the fluorspar mine, Southern Illinois

Marangin Simatupang

ANALYSIS OF MINING MECHANIZATION

IN THE FLUORSPAR MINES, SOUTHERN ILLINOIS

BY

MARANGIN SIMATUPANG

A

THESIS

submitted to the faculty of the

SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI

in partial fulfillment of the work required for the

Degree of

MASTER OF SCIENCE IN MINING ENGINEERING

Rolla, Missouri

1958

Approved by - C. R. Christiansen
Professor of Mining Engineering

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Mr. R. Gill Montgomery, General Manager, Minerva Oil Company, Mr. H. E. Bailie, General Superintendent, Ozark Mahoning Company, and Mr. W. S. Skeels, General Superintendent, Aluminum Company of America for permission to visit their mines and also for their assistance in providing the necessary data. The cooperation of the mining engineers, mine supervisors and shift bosses of the visited mines is also gratefully acknowledged.

The author is greatly indebted to Professor C. R. Christiansen of the Mining Department, Missouri School of Mines and Metallurgy, for his advice and constant guidance throughout the preparation and completion of this investigation.

Thanks are due to Mrs. A. K. Horrom for typing the paper.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

INTRODUCTION

The purpose of this study is to analyze the underground mechanization in the fluorspar mines in Southern Illinois. The mining mechanization in this district is confronted with manifold problems which are typical of most small or medium size mines.

The ore reserve in each mine is not very large. The method of development had to be planned accordingly such as not to exceed the depreciative capacity of the deposit.

The ore bodies consist of thin bedded layers or small veins. This thickness controls the sizes of the equipment to be used.

The mining operations always lack skilled equipment operators. In a large mine the company is able to provide pre-training before any new operator is assigned to a certain job, while in a small mining operation, this cannot always be done.

This district produces approximately one half of the United States fluorspar domestic production (52% in 1957). The fluctuation of the market price has a fast impact on the operations in the district. The decreasing price in the last few years caused by the cheap imported fluorspar that flows into the domestic market, together with the increasing labor cost, requires that the mining companies introduce more mechanized production methods so as to reduce costs.

In this paper the author evaluates these problems first with the operational or process analysis. The second is the study of the employed equipment, their performance and efficiency, with the aid of the time studies.

The human efforts involved in the underground production processes, and the economic effects of the application of certain types of equipment will also be investigated. Conclusions are presented after the discussion on the drilling, loading and haulage operations.

For the field studies, the author obtained the permission from the three major companies in the district, the Minerva Oil Company, the Ozark Mahoning Company and the Aluminum Company of America to visit the following mines:

1. Mine No. 1, Cave in Rock, Minerva Oil Company
2. Crystal Mine, Cave in Rock, Minerva Oil Company
3. West Green Mine, Cave in Rock, Ozark Mahoning Company
4. Oxford Mine, Cave in Rock, Ozark Mahoning Company
5. Hill Mine, Cave in Rock, Ozark Mahoning Company
6. A. L. Davis Mine, Cave in Rock, Ozark Mahoning Company
7. Fairview Mine, Rosiclare, Aluminum Company of America

The field work was accomplished during the period of June 3, 1957 through July 31, 1957. With the aid of the companies the author ran the time and motion studies, and collected the necessary information.

REVIEW OF THE PREVIOUS WORK

From the available literature and information, the author concluded that there had been no work reported comparable to this investigation.

The adaptation of different underground equipment at Minerva Oil Company's Mine No. 1 at Cave in Rock was reported by R. Gill Montgomery(1).

---

(1) Montgomery, Robert Gill, Adaptation of Diesel, Rubber-tired Loading Equipment to a Bedded Fluorspar Mining Problem. Thesis for E.M. Degree at the Missouri School of Mines and Metallurgy, T 1046, 1953, pp. 7-28.

The report describes the continuous attempt of the Company to mechanize its Mine No. 1.

Time study on jumbo drilling in the Tri-State Mining District had been made by Forrester and Fuller (2). A few procedures therein are

---

(2) Forrester, J. D., and Fuller, Julian A., An Analysis of Man-Power Efficiency in Drilling Procedures in the Tri-State Mining District. Missouri School of Mines and Metallurgy publication, Bulletin No. 1, Vol. 17, March 1946, pp. 4-8.

---

utilized in this study.

Time study procedures applicable to loading and gathering equipment in the underground coal mines were published by the Pennsylvania State College (3). This publication, together with a report on time

---

(3) Mineral Industries Experiment Station, Pennsylvania State College, More Profit in Mechanical Mining Through Studies of Loading and Gathering Performance. Bulletin No. 50, 1952, pp. 3-35.

---

studies of underground haulage in the Tri-State Mining District made by Wheelock, (4) contributed ideas to the time study methods for the truck

---

(4) Wheelock, Leroy King, An Efficiency Analysis of Underground Haulage in the Tri-State Mining District. Thesis for M.S. Degree at the Missouri School of Mines and Metallurgy, T. 999, 1952, pp. 30-37.

haulage in this investigation.

GEOLOGY

The fluorspar deposits of Southern Illinois (see location map Fig. I), can be divided into three groups, (1) veins, (2) flat bedded deposits, and (3) residual deposits.

The veins are fissure fillings along a system of SE-NE vertical faults that intersect the Mississippian and Pennsylvanian formations in this region. Deposits of this type are productive in the Rosiclare area; among them are the Blue Digging, Good Hope and Argo veins which are mined by the Aluminum Company of America. The thickness (width) of the veins ranges from a mere film up to 30 feet (5).

---

(5) Feller, J. Marvin, Morgan, Robert M., and Tippie, Frank E., Geology of the Fluorspar Deposits of Illinois. Illinois State Geological Survey Bulletin No. 76, 1952, pp. 27-41.

The flat bedded deposits are replacement type mineralization of the Fredonia and upper Rhenault limestones. These formations dip slightly (average 7 degrees) to the Northeast (N 50 E). The mineralization occurred in one or both sides of the main faults or minor fractures along the above mentioned fault system. The ore deposits in Minerva's Mine No. 1, Crystal Mine, West Green Mine, A. L. Davis Mine, and Hill Mine are all flat bedded deposits.

The residual deposits were formed by the weathering of the outcrops of either veins or flat bedded deposits. In this process the gangue material, limestone, has been fractured and dissolved by the surface water, the residual enrichment then took place in situ. None of the deposits in the mines that were visited belong to this type of deposit.

Fluorite is the main ore mineral in both vein and flat bedded deposits. Associated with the fluorite are lesser amounts of galena and sphalerite. In some mines the amount of either Zn or Pb is too small to be recovered in the mill. The gangue material consists mainly of calcite, other carbonate minerals, and baryte.

MINING PRACTICE

Flat Bedded Deposits

The roofs of the flat bedded deposits consist of consolidated sandstone. The thickness of the ore layers never exceeds 15 feet. This condition leads to the application of the room and pillar mining method. With the exception of the Crystal mine which was opened with a horizontal adit, the other ore deposits were opened by shaft sinking. Rooms as wide as 20 to 40 feet are mined and irregular pillars of 10 to 20 feet in diameter are left. (See Figure 2) Bad roofs are temporarily supported with expansion type roof bolting. The extraction of the ore varies from 60 to 80%. As the mining proceeds to the boundary of the deposits, the pillars can be extracted with a retreating system. By this method the overall extraction can be as high as 90%.

The equipment used in the different mines is listed in Table 1. In Mine No. 1 (Minerva) a jumbo drill is employed. All other mines use air leg drills in the stopes. The irregularity of the ore beds is usually towards the floor. It is seldom necessary to apply the benching method in the drilling. The ore left in the floor can be later drilled as a clean-up operation.

In faces higher than 5 feet, central V-cut or burncut rounds are popular. Slabbing rounds are favored in lower faces or in the extraction of the pillars. The holes are charged with 45 to 60% dynamite and detonated with safety fuse and blasting caps.

The portable slusher (slusher ramp) is the only type of loader used in the daily loading operations. Different kinds of front-end loaders and rocker shovel are merely used in the development or as reserve equipment.

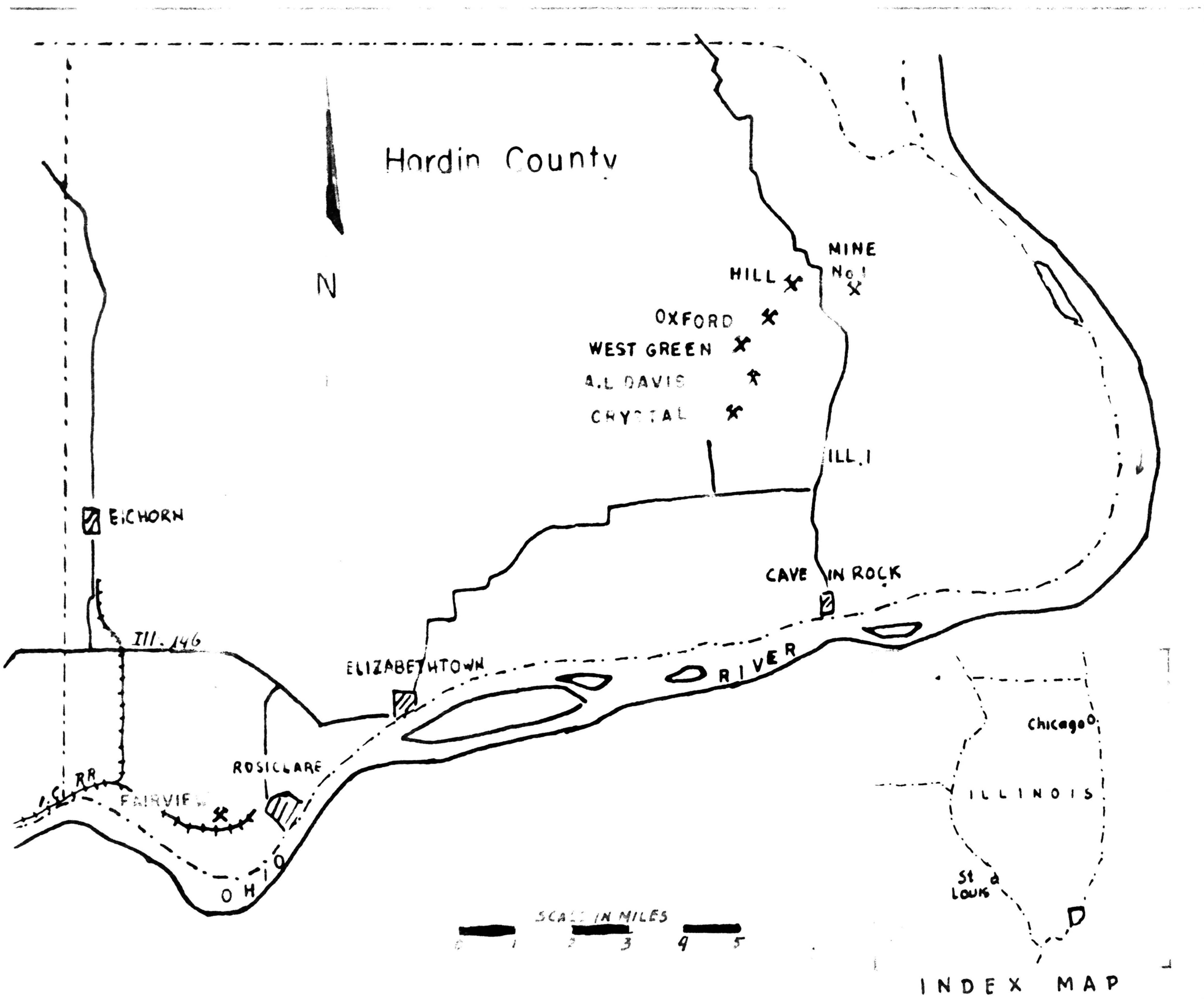
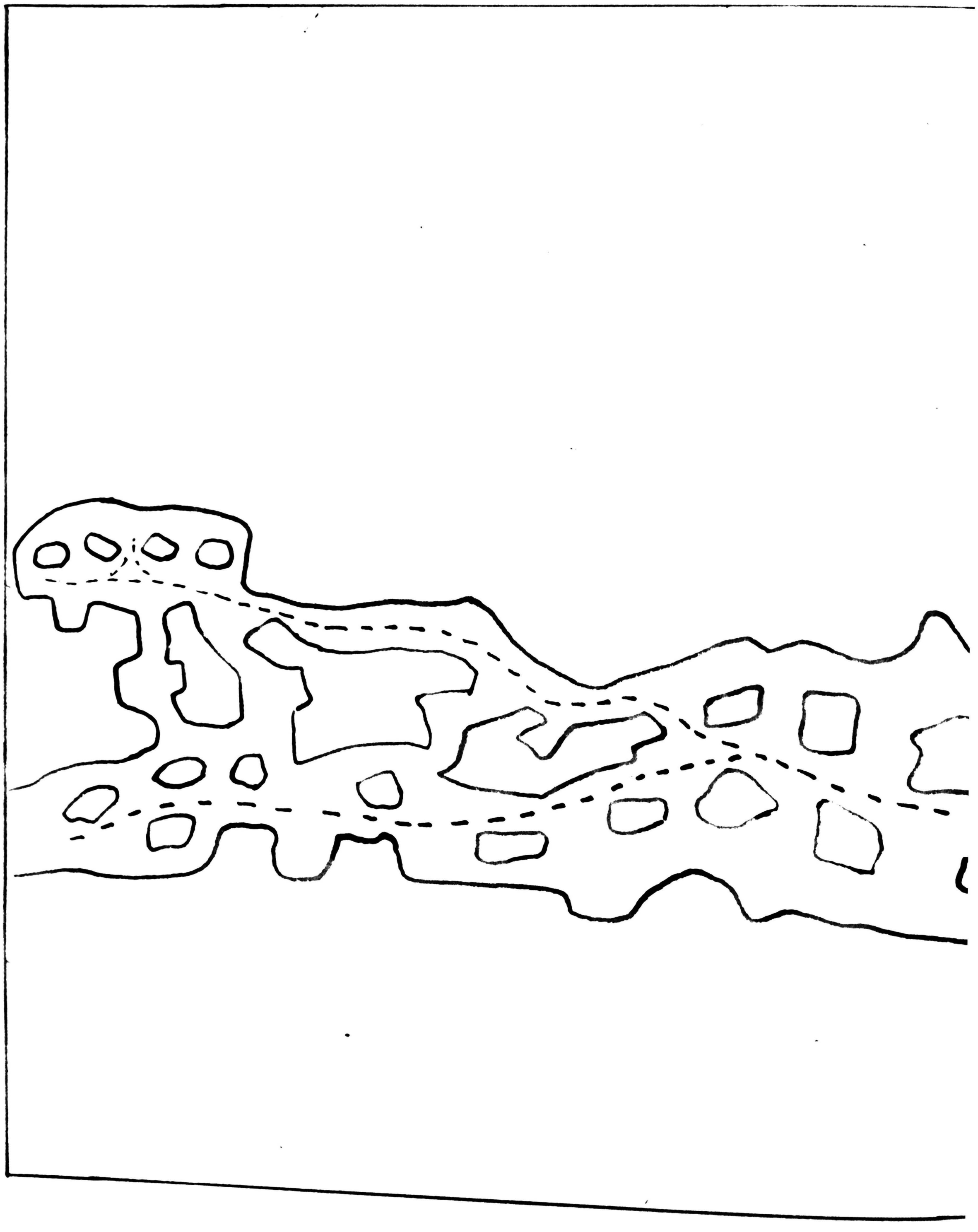


Figure 1. Location Map



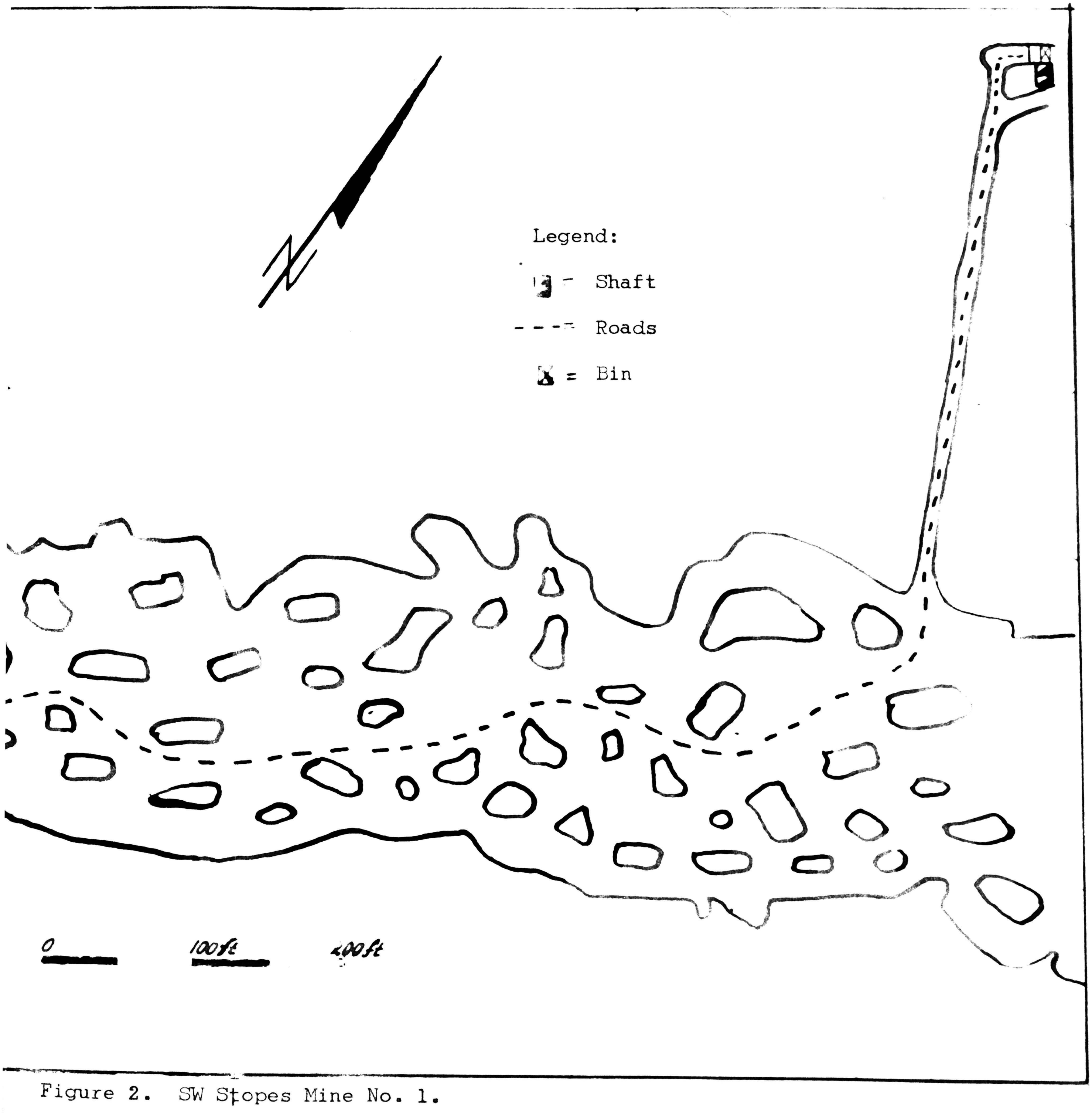


Figure 2. SW Stopes Mine No. 1.

TABLE I

Equipment Employed in Illinois Fluorspar Mines

Mine	Drilling	Loading	Haulage	Hoisting
Mine No. 1 (Minerva)	Jumbo drill and airleg	Portable slusher	Trucks	Skip
Crystal	Airleg	Portable slusher	Trucks	Skip*
West Green	Airleg	Portable slusher	Diesel Locomotive and 1 ton cans	Can hoisting
Oxford	Airleg	Portable slusher	Battery locomotive and cars	Cage hoisting
A. L. Davis	Airleg	Portable slusher	Battery locomotive and cans	Can hoisting
Hill	Airleg	Portable slusher	Trucks	Skip
Fairview	Stoper	Stationary slusher & chute loading	Battery locomotive and gable bottom dump cars	Skip

* This skip is in the old shaft and used only in an emergency situation.

In the underground haulage, both track and truck haulage are used.

Vein Deposits Fairview Mine;

Access to the mine was gained by shaft sinking in the waste rock. Cross-cuts in levels of 100 feet vertical intervals were driven from the shaft to vein. Horizontal drifts in the veins were then driven from the crosscuts. Two drifts driven from successive crosscuts were connected with lined manways separated by distances of 100 feet. (See Figure 3).

One block of 100 by 100 feet ore, between two manways and two drifts is mined with slusher type shrinkage stoping, a modification of the conventional gravity shrinkage stoping.(6) Two ore chutes built near the manways, serve as ore passes from the ore block. The next stoping step is to drive an undercutting drift about 6 to 10 feet above the lower drift, so as to leave a safety pillar to protect the drift. The stoping then proceeds from the undercutting drift to the upper drift. Successive slices of 8 to 10 feet of ore are drilled and blasted. Stopers with single-use detachable steel bits are used to drill slabbing rounds in the stopes. The drill holes are loaded with 45% gelatin dynamite and detonated with safety fuse and blasting caps.

About one-third of the broken ore (the volume of the broken ore is about 30 percent greater than that of the ore in place) has to be slushed regularly to the ore chutes with scraper hoists, to provide enough room for the drillers to work in the stopes. From the ore chutes the broken ore is loaded into Gable-bottom cars for transportation to the shaft station. Trains of cars are drawn by storage battery locomotives.

---

(6) Clark, George B., and Harrison, William H., Jr., Slusher Solves the Shrinkage Problem, E.& M. J., May 1948, Vol. 149, pp. 80-81.

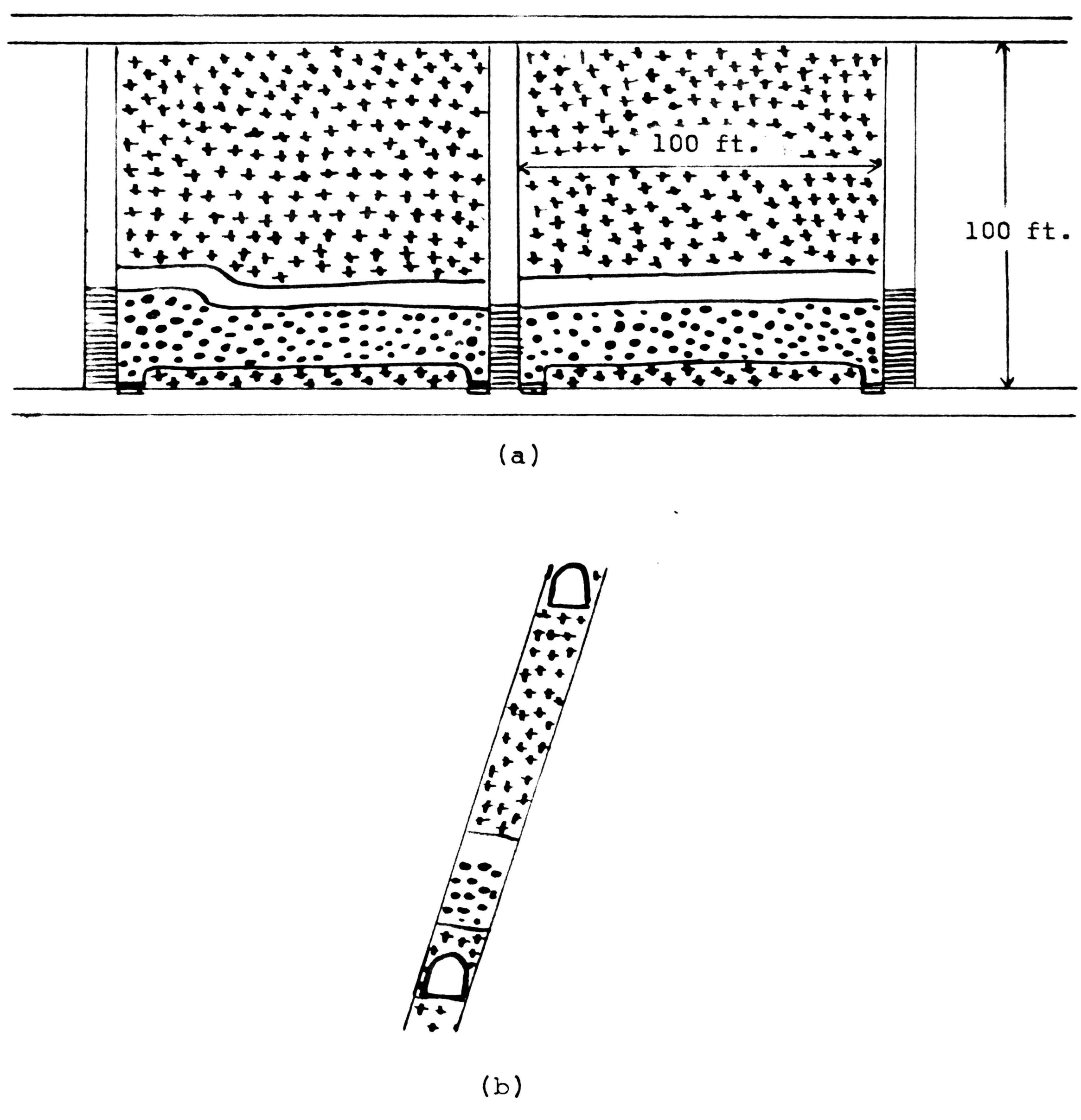


Figure 3. Modified Shrinkage Stopes. Fairview Mine.

(a) Longitudinal Cross Section
(b) Vertical Cross Section

DRILLING

In the drilling operations in the fluorspar mines of Southern Illinois airleg, stoper and jumbo drills are in use. There had been contradictory results in the attempts of the companies to replace the airleg drills with jumbo drills in the flat bedded mines.

According to the available information, the use of a jumbo drill in the West Green Mine was discontinued in 1956. The lack of skilled operators was probably the main reason for the failure of the use of the jumbo drill in this mine. In the same year a jumbo drill was replaced by airleg drills in the Crystal Mine. Rough floor and irregular headings resulted in the lack of maneuverability of the jumbo drill, thus the Company decided to put it out of operation. At the present time the only jumbo drill in operation is in the Minerva Mine No. 1 where the method of drilling has been employed since 1946.

In the vein mines stoper drills are still considered the most suitable drilling machines.

Even with the same type of drilling equipment, in very similar mines the drilling practice differs from one company to another. As will be discussed later, this difference is partly due to the labor agreement between the companies and unions.

In this mining district the drilling operation is not considered as a separate operation but as a part of breaking operation, which includes drilling, charging and blasting. This means that the drilling crews are to charge and to blast their drilled holes. In the accounting system the cost of drilling, blasting and powder are combined under one account.

The aim of time studies in the drilling as well as in other operations in this report needs clarification.

Carroll stated that the primary function of time study is to procure the correct time allowances for every operation that should come within the wage incentive plan. (7) This function is mostly applicable to

---

(7)Carrol, Phil, Jr., Time Study for Cost Control. McGraw Hill Book Co., 1943, p. 9.

---

to machine work, where operation on each machine is standardized. (8)

---

(8)Harley, G. T., Time Study Methods for Mining Operation. Engineering Mining Journal, Vol. 123, 1927, pp. 722-729.

In the mining operations, however, an operator may handle the same equipment every day, but the working condition is always changing. From time to time he is to perform unpredictable motions (activities) which do not belong to the basic work-cycle.

The primary aim of the time studies in the mining operations should be in the first place, to analyze the methods and the equipment. It is defined by Alford (9) as "a searching scientific analysis of methods and

---

(9)Alford, L. P., Principles of Industrial Management. The Ronald Press Company, 1944, p. 471.

---

equipment used or planned in doing a piece of work, development in practical detail of the best way of doing it, and determination of time required."

AIRLEG AND STOPER DRILLS

An airleg consists of two or three telescopic pipes, which can be extended by the compressed air (Figure 4). The compressed air can be lead to or released from the pipes, through a valve regulator in order to extend or to shorten the leg. A drilling machine is attached with a ball joint to the upper end of the inner pipe. The lower end of the outside pipe is provided with V-shaped legs for the anchorage of the airleg during the operation. Different kinds of drilling machines are used, and the Sandvik Coromant drill steel with tipped tungsten insert chisel bits are popular in the district. The bit diameter varies from $1\frac{1}{4}$ to 1 7/8 inches.

A stoper consists of an airleg and a drilling machine which are built together as a unit. The compressed air in the leg aids to increase the thrust of the bit. The stopers employ hexagonal steels and throw-away bits (detachable bits). A stoper is suitable to drill up-holes in the overhand stopes. The stoper is widely used also in the flat bedded mines for the roofbolting.

The airleg and stoper drills can be considered as less mechanized equipment. This statement implies that many of their basic motions have to be done by hands. (Without any aid from the mechanism of the equipment.) The efficiency is more dependent upon the use of human energy than is the case when the more mechanized equipment is employed. For the less mechanized operation, the operational analysis, that is, the study of all major factors which affects the operation, could reveal enough information for the efficiency studies. (10)

---

(10) Mainard, Lowery, and Stegemerten, Time and Motion Study, McGraw Hill Book Company, 1940, p. 52.

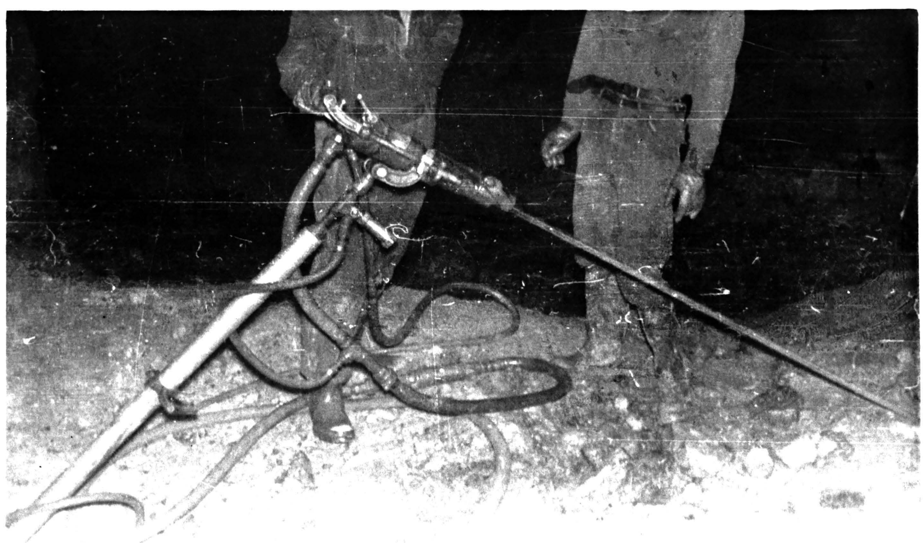


Figure 4. Airleg Drill

In the Crystal Mine, airleg drills of different manufactures are used. In this mine an airleg is run by a driller and a helper. During the actual drilling, the driller maneuvers the airleg. The helper aids in collaring the holes, preparing the face, setting up and maintaining the airleg drill.

The drilling is performed only during the first half of the shift, that is, from 7 to 11:30 A.M. for the day shift, and from 3:30 to 8 P.M. for the evening shift. During the second half of the shift (12 to 3:30 P.M. for the day shift, and from 8 to 11:30 P.M. for the evening shift), the drillmen blow the holes, charge them with explosives, and about 15 minutes before the end of the shift the rounds are fired. A round of 20 to 30 eight-foot holes is assigned to each drilling crew every day.

The same practice is followed in all Ozark Mahoning mines, except that only one driller runs an airleg drill.

In the Fairview mine stoper drills are used. A driller runs a stoper on a daily contract basis (unwritten contract) of 26 six-foot holes per day.

Simplified time studies for the airleg and stoper drilling operations were conducted in the West Green, Crystal and Fairview mines. The following job sub-subdivisions were timed with a stopwatch:

Setting up (abbr. Su): to bring the drilling equipment to the front, to lead the water and compressed air lines, to connect the lines to the drilling machine, to disconnect the lines at the end of the shift, to replace the drilling machine and the water and compressed air lines from the front at the end of the shift, and other face preparation.

Drilling (D): collaring, maneuvering, actual drilling and to change the bit.

Maintenance (M): To lubricate the drill machine.

Delays (Ds): Idleness, mechanical failures and other delays caused by natural condition such as roof falling, etc.

TABLE II

Time Study on Airleg and Stoper Drills
Four and One-Half Drilling Hours Per Shift

Mine	Date of Study	Drilling Machine	Su		D		M		Total prod. Time		Ds	
			Minute	%	Minute	%	Minute	%	Minute	%	Minute	%
Crystal	June 10-11 1957	Airleg	26	9.6	163	60.3	10	3.7	199	73.6	71	26.3
West Green	July 8-9 1957	Airleg	25	9.2	170	63.0	7	2.6	202	74.8	68	25.2
Fairview	July 22-23 1957	Stoper	34	12.6	155	57.5	3	1.1	192	71.3	78	28.7

TABLE III
Drilling Performance Rating

Mine	Drilling Machine	No. of Men Per Drill	Average ft. Per Shift	Ft./man/shift	Ft.man/prod. Hour
Crystal	Airleg	2	192	96	$\frac{96 \times 100}{4.5 \times 73.6} = 27.2$
West Green	Airleg	1	216	216	$\frac{216 \times 100}{4.5 \times 74.5} = 58.9$
Fairview	Stoper	1	156	156	$\frac{156 \times 100}{4.5 \times 71.3} = 48.6$

JUMBO DRILL

In the Minerva Mine No. 1 a two-sash self propelled jumbo performs about 80% of the drilling operation. Further specifications of the jumbo drill are as follows (Figure 5):

Type: Gardner Denver Mobil Jumbo

Power: 15 HP radial type air motor

Mount: Rubber tires

Control system: Hydraulic

Boom length: 14 ft.

Drifter length: 12 ft.

Maximum operating height: 14 ft.

Maximum operating width from a single position: 25 ft.

Drilling machines: Left drifter with 4" Joy rock drill
Right drifter with $3\frac{1}{2}$" Ingersoll Rand rock drill

Minimum clearance width: 7'6"

Bit: Throw-away bit $1\frac{1}{2}$ - 1 7/8" diameter

The drilling crew consists of a driller and a driller's helper. The driller maneuvers the jumbo; and the helper changes the bits, trims the face, aids in directing the drilling pattern and fetches the necessary supplies.

The drilling is performed during the dayshift, and the first half of the evening shift. During the second half of the evening shift, the evening drilling crew charges and blasts the holes. It is a practice in this mine, that the drilling crew completes a drilling round of 30 to 35 ten-foot holes for the day shift, and 20 to 25 holes for the evening shift.

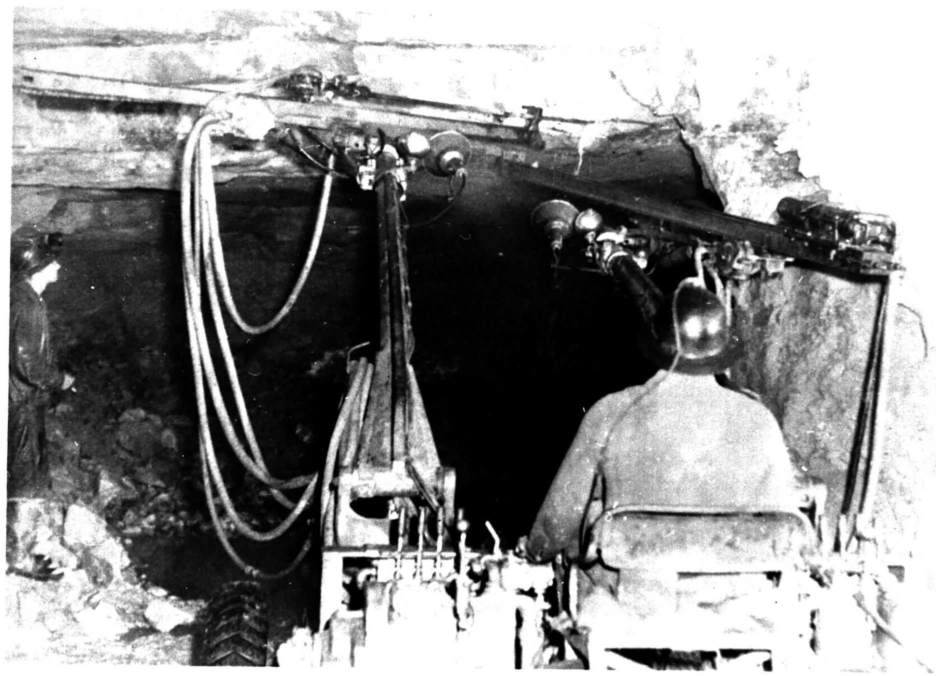


Figure 5. Jumbo Drill
Courtesy of Minerva Oil Company

Time Study on the Jumbo Drill

A time study was conducted for 2 consecutive day shifts in the Mine No. 1.

For more accuracy, which is always required for practical purposes, time studies for four or more consecutive days is highly recommended.

After studying detailed motions which contribute the whole daily activities performed by the jumbo drill, the drilling cycle is classed into nine job subdivisions. Each subdivision consists of several motions. The nine subdivisions are:

1. Drilling preparation (Dp): To drive the jumbo drill from the standby position to the working place, to replace the jumbo from the finished heading to the next heading, to replace the jumbo from the heading to the standby position at the end of the shift, to connect and disconnect the water and compressed air lines at the beginning and at the end of the shift.

2. Drilling (D): Actual drilling and collaring.

3. Maneuvering (M): To maneuver the drills from a finished hole to the next, to change the bit.

4. Travel (T): It is the custom in this mine that the underground workmen start and end the shift at the top of the shaft. They have to go also to the surface for lunch. Four times traveling between the top of the shaft and the working place, is included in the drilling cycle.

5. Maintenance (Me): Lubrication and cleaning of the drilling machines and the motor.

6. Face preparation (Fp): To trim the roof and the face and safety inspection.

7. Waiting for other (Wo): Any time (occasion) that one drilling machine is prevented from operating by the other, such as when changing the drill steel, stuck steel, or when there is no other holes to be drilled at the completion of the rounds. Other delays caused by other equipment in the mine, such as lack of compressed air, delays by the surveying activities, etc. are included into this subdivision.

8. Mechanical delays (Dm): All mechanical failures, stuck steel, broken air hose, broken flood light, etc. The stuck steel is included in this subdivision for the reason that it can be regarded as the result of improper operation. (To some extent it is caused by the natural condition of the rock, e.g. the sudden change of the properties of the rock, the existence of cavities, etc.)

9. Other delays (Do): Idleness, late starting of the shift, too early quitting, etc.

In the above classification all noncyclical motions are grouped into particular subdivisions in accordance to their effect on the whole operation cycle. For instance, the change of steel occurs only when the old steel is broken. This happening is unpredictable, so it is classed as a mechanical delay. On the other hand the bits have to be changed regularly, as they wear out. The bit change is then grouped into maneuvering subdivision.

The first three subdivisions contribute to the productive use of the jumbo drill. The "travel," "maintenance," "face preparation" and "waiting for others" are all necessary delays, while the "mechanical delays" and "other delays" are unnecessary delays.

The job subdivisions then can be expressed in the following scheme:

Drilling cycle:	Productive time	Drilling preparation (Dp)
		Drilling (D)
		Maneuvering (M)
	Necessary Delays	Travel (T)
		Maintenance (Me)
		Face preparation (Fp)
		Waiting for others (Wo)
	Unnecessary Delays	Mechanical delays (Dm)
		Other delays (Do)

A symbol is assigned to each subdivision for easy and fast recording of the time in the working paper (work sheet). Each drilling machine can be assumed independent of the other and each is timed separately.

Consecutive motions for each subdivision are timed with a stop watch. The accumulated time for each subdivision is transferred to the consolidation sheet.

The consolidation sheet for this drilling time study is shown in Table No. IV, and the Table No. V shows the performance rating. The time distribution can be better visualized in Chart No. 6.

TABLE IV

Time Study Consolidation Sheet

Two sash jumbo, 2 man crew
Mine: Mine No. 1 Minerva
Date of Observation: June 10-11, 1957

Subdivision	Left Minute	%	Right Minute	%	Average Minute	%
Drilling Preparation	19.75	4.1	19.75	4.1	19.75	4.1
Drilling	236.50	49.3	229.75	47.9	233.12	48.6
Maneuvering	35.50	7.4	23.00	4.8	29.25	6.1
Total Productive Time	291.75	60.8	272.50	56.8	282.12	58.8
Travel	45.25	9.4	45.25	9.4	45.25	9.4
Maintenance	24.50	5.1	24.50	5.1	24.50	5.1
Face Preparation	5.	1.0	5.25	1.1	5.12	1.05
Waiting for Others	12.50	2.6	48.50	10.1	30.50	6.35
Total Necessary Delays	87.25	18.1	123.50	25.7	105.37	21.9
Mechanical Delays	51.25	10.7	35.50	7.4	43.37	9.05
Other Delays	49.75	10.4	48.50	10.1	49.12	10.25
Total Unnecessary Delays	101.00	21.1	84.	17.5	92.49	19.30
Total	480.00	100.0	480.00	100.0	479.98	100.00

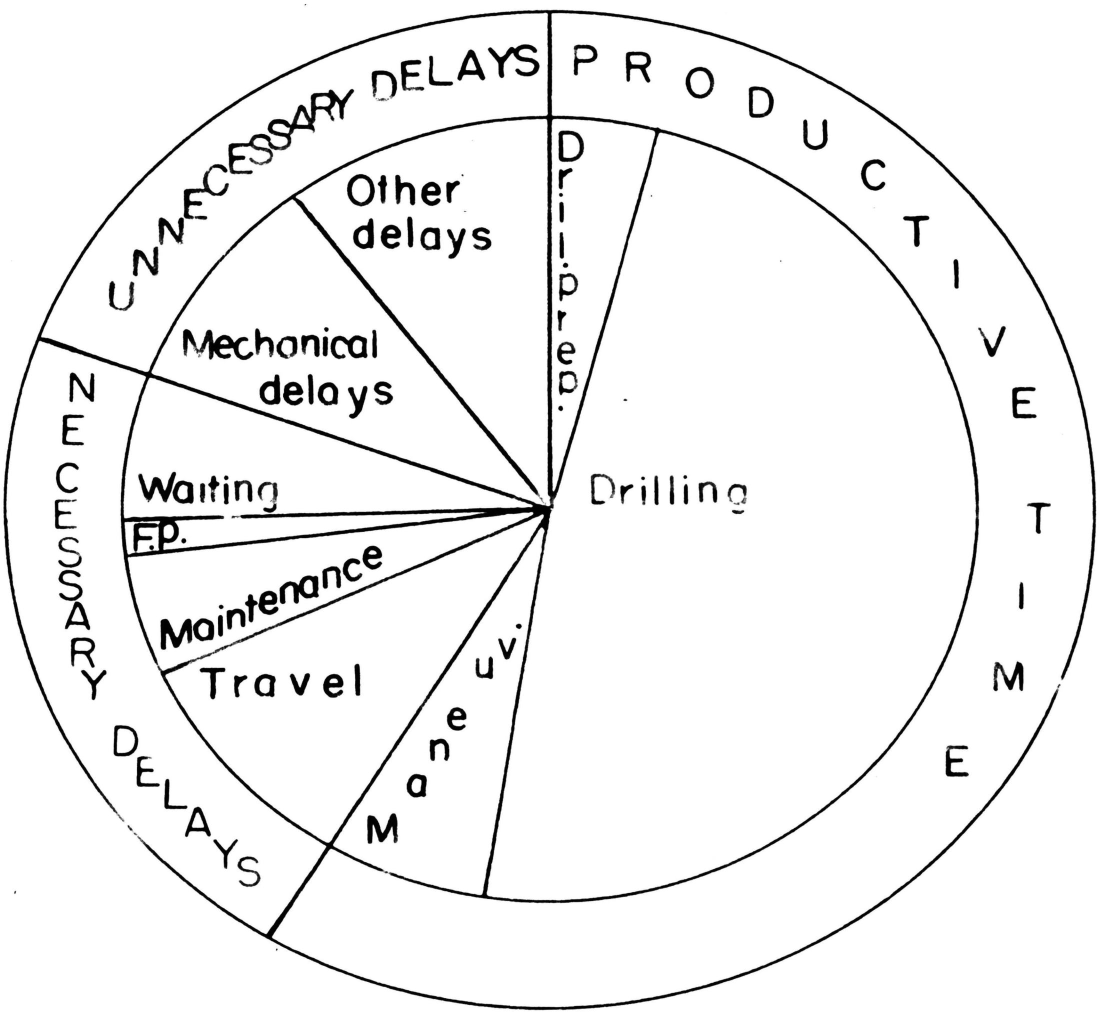


Figure 6. Time Distribution Chart.
Jumbo Drill Mine No. 1.

TABLE V

Performance Rating Jumbo Drill

Footage drilled	Left: 168 ft. Right: 144 ft.
Ft. per jumbo per shift	312
Ft. per man shift	156
Average ft. per shift for the month	318
Ft. per man shift prod.hour:	$\frac{156 \times 100}{8 \times 58.8} = 33.2$

CONCLUSIONS OF THE DRILLING STUDIES

It is obvious that a drilling crew of two men to run an airleg results in a very low efficiency. The need of a helper is only justified when collaring a hole higher than 5 ft. (higher than the driller). By proper maneuvering and gradual application of the thrust a driller can collar the hole more easily.

The proportion of the drilling time compared to the charging and blasting time ($4\frac{1}{2}$ hours to $3\frac{1}{2}$ hours) does not represent an agreeable ratio. Three hours drilling time to one hour charging and blasting time is believed to approach a better ratio. Where there are three or more drilling crews in a mine, the separation of drilling crew from the charging and blasting crew is also feasible.

The non-incentive daily contract system results in the misvaluation of the work performed by a driller at different working conditions. An incentive contract system, based on a standardized time requirement (which can be derived from the time study) to drill one foot at a certain working condition will initiate the will of the driller to improve his efficiency. With this system a better work evaluation can be obtained.

With a better job assignment, and supervision the drilling performance of the airleg and stoper can be improved.

With better planning of the layout of the mines, the jumbo drill can be used in all these flat bedded mines. Considering the fact that the ore is harder in Mine No. 1, and that the hole diameter is larger (1 7/8" compared to $1\frac{1}{4}$") with the jumbo, the number of feet per man shift per productive time is relatively high.

Time study on the jumbo drill shows:

a. The driller has the preference to use the left drill machine during the time that one of the drills has to wait for the other. This is caused by the difference in the capacity of the drilling machines. This can be eliminated by providing each drifter with the same drilling machine.

b. The high percentage of necessary delays can be partly decreased. Of these the travel time should be eliminated from the drilling cycle.

c. Of the mechanical delays, the stuck steel and broken steel represent the highest percentages in this subdivision. Broken steel is caused by the great thrust or twist applied on the steel, while stuck steel is caused by too rapid penetration of the bit in the spotty softer formation. Better education of the operator and better maintenance of the jumbo drill will decrease this type of delays as well as other mechanical delays.

d. The percentages of "unnecessary delays" is lower for the jumbo than the airleg and stoper drills. This is partly the result of less fatigue.

LOADING

During the history of the mining mechanization in the Southern Illinois fluorspar mining district, the rocker shovel type loader was (Figure 7) frequently considered to be the answer to the loading problem. It was the oldest type of mechanical loader used in the district. At the present time, the rocker type loader is used only in drifting, crosscutting and other development workings.

Considering the traction movement of a rocker shovel (during the operation) its capacity is expected higher than a front end loader with the same bucket size. It is also easier to operate and to maintain. The disadvantages of a rocker shovel in these mines are enumerated as follows:

a. A track-mounted air-driven rocker shovel has a limited maneuverability.

b. The excessive wear of the bucket during the crowding

c. Not adaptable to rough floor

d. The dumping height is relatively high, requiring high backs.

In 1957 the Ozark Mahoning Company introduced an electric driven, crawler mounted rocker shovel in its Oxford mine. It has greater maneuverability and the crawler mount facilitates a stable crowding action. The electric rocker shovel was used to load the ore into rail cars. The long distances between the muck piles and the rail tracks which in some places reach up to 80 feet resulted in a very low efficiency.

Different types of front end loaders were also used in most of the flat bedded mines. A front end loader has great maneuverability. Compared to a rocker shovel, a front end loader requires more skillful operators and careful maintenance. A front end loader has a high

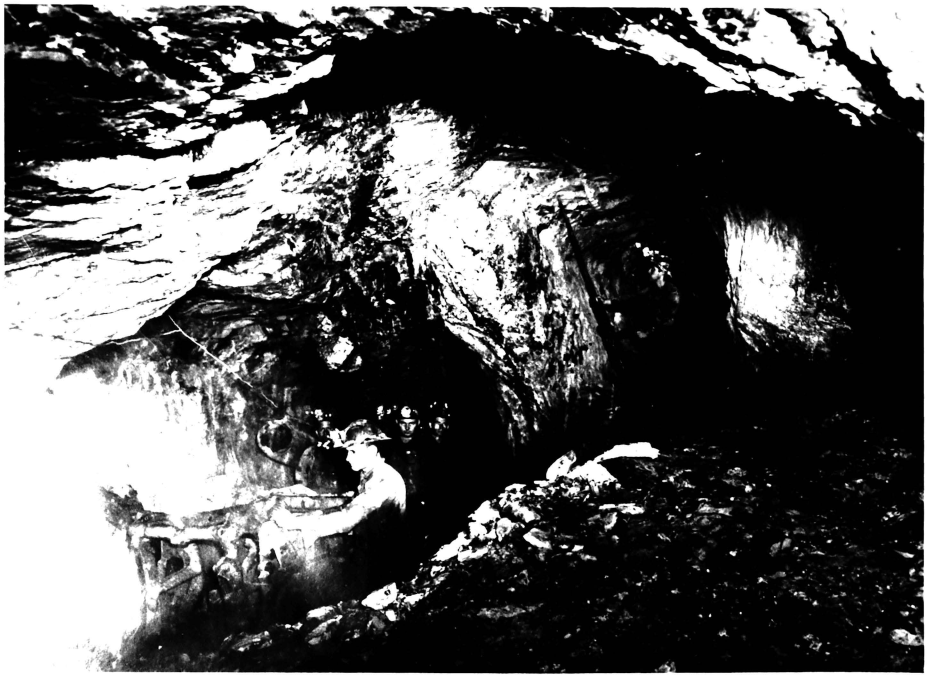


Figure 7. Eimco Rocker Shovel in Drifting
Courtesy of Aluminum Company of America

Figure 8. Payloader.

dumping height, and it is not adaptable to rough floor (see back tires of the payloader - Figure 8).

In 1952 Gill Montgomery (11) reported a lower loading cost per ton

(11) Montgomery, Robert Gill, op. cit. p. 3.

in the Minerva Mine No. 1 with the then newly purchased diesel $1\frac{1}{2}$ yard Hough payloader. Long before the payloader was fully amortized, the break down time and the maintenance cost had increased so high that it was later put out of regular loading operation. At the present time, front end loaders in the Mine No. 1, Crystal Mine and West Green mine are used for road maintenance or as reserve loaders.

Table I shows that the portable slusher is the only type of loader used in the production loading in all the flat bedded mines. The portable slusher was adopted in this mining district shortly after the acceptance of scraper loaders in the Tri State lead mines in 1936. Generally a portable slusher has the following advantages in these mines:

a. It is adaptable to low headings and rough floors. From a single position a portable slusher can slush the ore from low headings or basin like floors up to 150 feet distance.

b. It is easier to build, to operate and to maintain a portable slusher. The companies can design and construct their own slusher ramps in their machine shops. These factors result in low first cost and low maintenance costs.

c. It has a better loading method. A portable slusher can be provided with a funnel like discharge to load into trucks, cars or cans. This makes it possible to distribute loads in cars or trucks with a minimum of spotting and shifting time.

d. Greater safety can be obtained. During the loading the operator stands far from the heading. This is important especially when robbing the pillars.

PORTABLE SLUSHER

A portable slusher, which is also called a slusher ramp, consists of a ramp (body) and a scraper hoist. The ramp can be mounted on rubber tires or on crawlers. The rubber tires last longer, but have less stability during the operation. Portable slushers in these mines are powered with 5 to 7½ HP electric motors for travel. The scraper hoist is of the triple drum type. Two of the drums are for the tail ropes and the other one for the pull rope. The two tail ropes can be anchored with sheave blocks and eyebolts at desired points in the face by fastening the eyebolts with wedges into drill holes. The scraper hoists are also driven by electric motors. The required power varies from 15 to 25 HP for 36 to 48 inch scrapers. Semi-hoe type scrapers are favored for coarse ore, while crescent types are also in use. The digging angle of the scrapers is 40° to 50°. It will provide proper digging for horizontal scraping as well as for scraping up slopes to a maximum of 22½°. The tail ropes and the pull rope are ½" to 3/4" diameter.

A portable slusher setup is shown in Figure 9. The two tail ropes are anchored to the stope wall so as the muck pile lies between the two tail ropes. By skillful maneuvering an operator can swing the scraper to clean up the ore outside the tail ropes area.

Time studies were conducted in two mines, one is for a portable slusher in Mine No. 1 which loads into 5-ton trucks (See Figure 10) and another for a portable slusher in West Green Mine which loads into cans. The difference between the two is that the latter has a smaller discharge opening thus loading has to be done more carefully to prevent the spilling of the ore. (Figure 11)

A man can operate a portable slusher daily. To reduce the breakdown time the holes for the anchorage of the tailropes have to be drilled

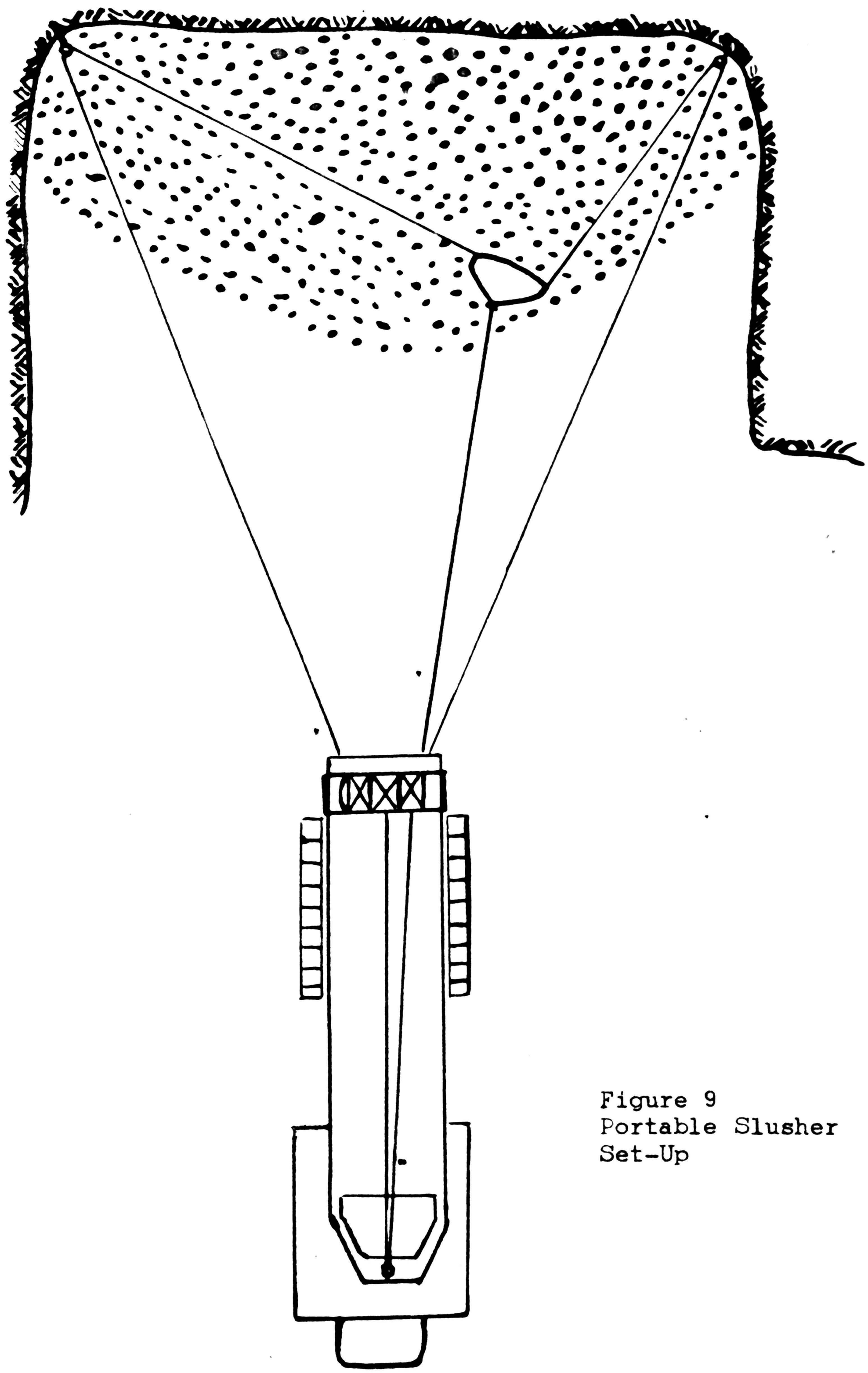


Figure 9
Portable Slusher
Set-Up

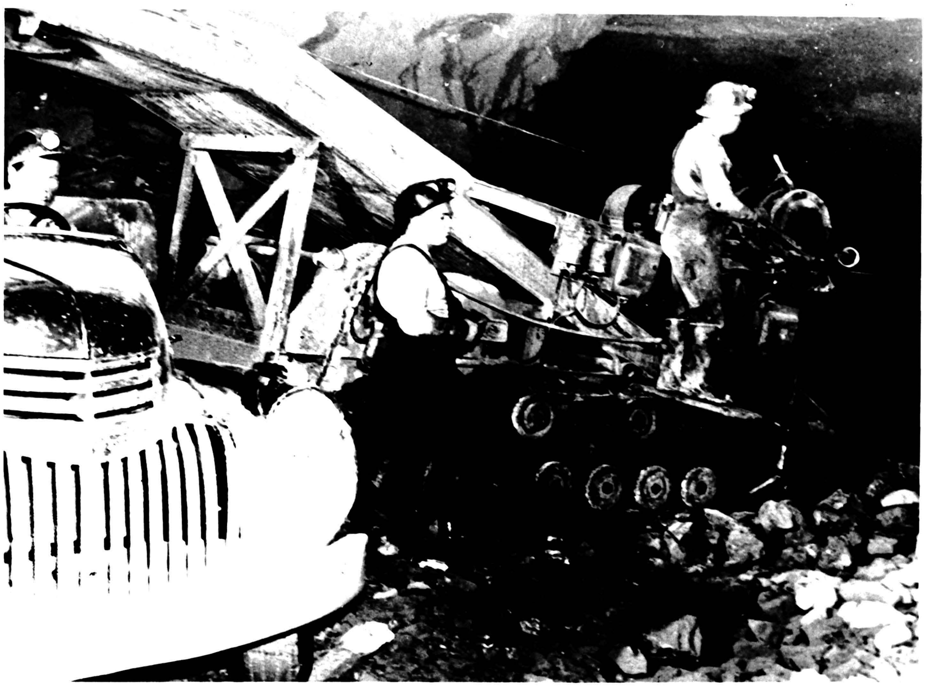


Figure 10. Portable Slusher Loading Into Truck.
Courtesy of Minerva Oil Company

Figure 11. Discharge Opening of a Scraper Loading Into Can.
West Green Mine.

by the drilling crew or by the maintenance crew. This has to be excluded from the loading cycle.

After studying the daily motion of the loading operations, the loading cycle has been divided into the following subdivisions:

1. Loading (L): To slush the ore from the muck pile and to discharge it to the trucks or cans.

2. Collecting (Lc): When there are no trucks or cans available to load into, the operator can slush the ore from the muck pile to a position closer to the ramp to reduce the dragtime for the next loading.

3. Setting up (Su): To drive the portable slusher to the working place, to set it up in operating position, to anchor the tail ropes, other activities to move the portable slusher after mucking a face to another muck pile and to drive it back to the standby position at the end of the shift.

4. Travel (T): The time spent by the operator from the shaft to the working place and back.

5. Face preparation (Fp): Safety inspection and roof trimming that cause delay of the loading operation.

6. Waiting (Wo): Any time that the loading is hindered by other operations such as secondary blasting, track replacement, no truck or can available to load into, and roof bolting.

7. Mechanical delay (Dm): Broken ropes, broken lamp, failure in anchorage, motor failure, and other mechanical failures.

8. Other delays (Do): Other delays such as when the operator leaves, late starting of the shift, too early quitting, etc.

The "loading," "collecting" and "setting up" contribute to the productive use of the loader. The "travel," "face preparation," and "waiting" are necessary delays to the progress of the loading operation, while the "mechanical delays" and "other delays" are unnecessary delays.

The loader activities were timed with a stopwatch. The time utilized continuously for a certain subdivision was recorded in field sheets, using a symbol system. The field sheet data was worked out and transferred to a consolidation sheet.

The consolidation sheets for the two time studies are shown respectively in Tables VI and VII. The performance ratings of the portable slusher are shown in Table VIII. The time distribution is better visualized in time distribution Charts 12 and 13.

TABLE VI

Portable Slusher Time Study Consolidation Sheet Mine No. 1

Date of Study: June 17, 1957.

Portable slusher specifications: Mount: crawler
Scraper: 42" semi hoe type
Average scraping distance: 35 ft.

Job Subdivision	Time in Min.	Time in %
Loading	181.50	37.80
Collecting	28.50	5.94
Setting up	33.75	7.81
Total productive time	243.75	51.55
Travel	48.00	10.00
Face preparation	19.50	4.06
Waiting for other	11.50	2.39
Total necessary delays	79.00	16.45
Mechanical delays	124.75	25.93
Other delays	32.50	6.77
Total unnecessary delays	157.25	32.70
Total	480.00	100.70

TABLE VII

Portable Slusher Time Study Consolidation Sheet
West Green Mine

Date of Study: July 11, 1957.

Portable slusher specifications: Mount: rubber tires
Scraper: 42" semi hoe type
Average scraping distance: 42 ft.

Job Subdivision	Time in Min.	Time in %
Loading	110.25	22.97
Collecting	91.50	19.06
Setting up	58.75	12.24
Total productive time	260.50	54.27
Travel	--*	--*
Face preparation	17.75	3.40
Waiting for others	108.25	22.55
Total necessary delays	126.00	25.95
Mechanical delays	37.50	7.81
Other delays	56.00	11.60
Total unnecessary delays	93.50	19.41
Total	100.00	99.63

*Travel time is excluded from the shift hours.

TABLE VIII

Portable Slusher Performance Rating

	Mine No. 1	West Green Mine
Percent total productive time:	51.25	54.27
Tons loaded/shift:	276	115
Tons per productive hour:	$\frac{276 \times 100}{8 \times 51.25} = 67.3$	$\frac{115 \times 100}{8 \times 54.25} = 26.5$
Minutes / ton (productive time):	$\frac{8 \times 60 \times 51.25}{276 \times 100} = .891$	$\frac{8 \times 60 \times 54.25}{115 \times 100} = 2.26$

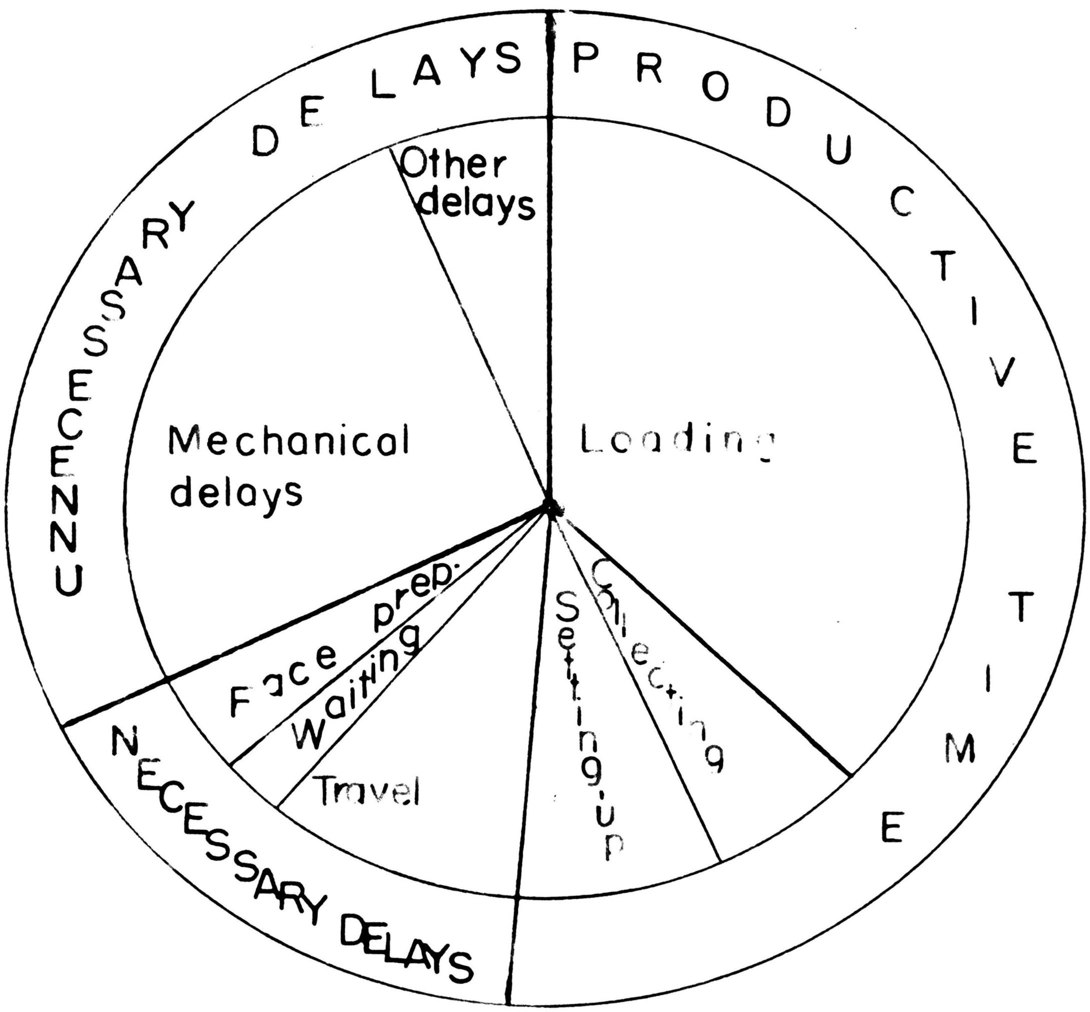


Figure 12. Time Distribution Chart.
Portable Slusher Mine No. 1.

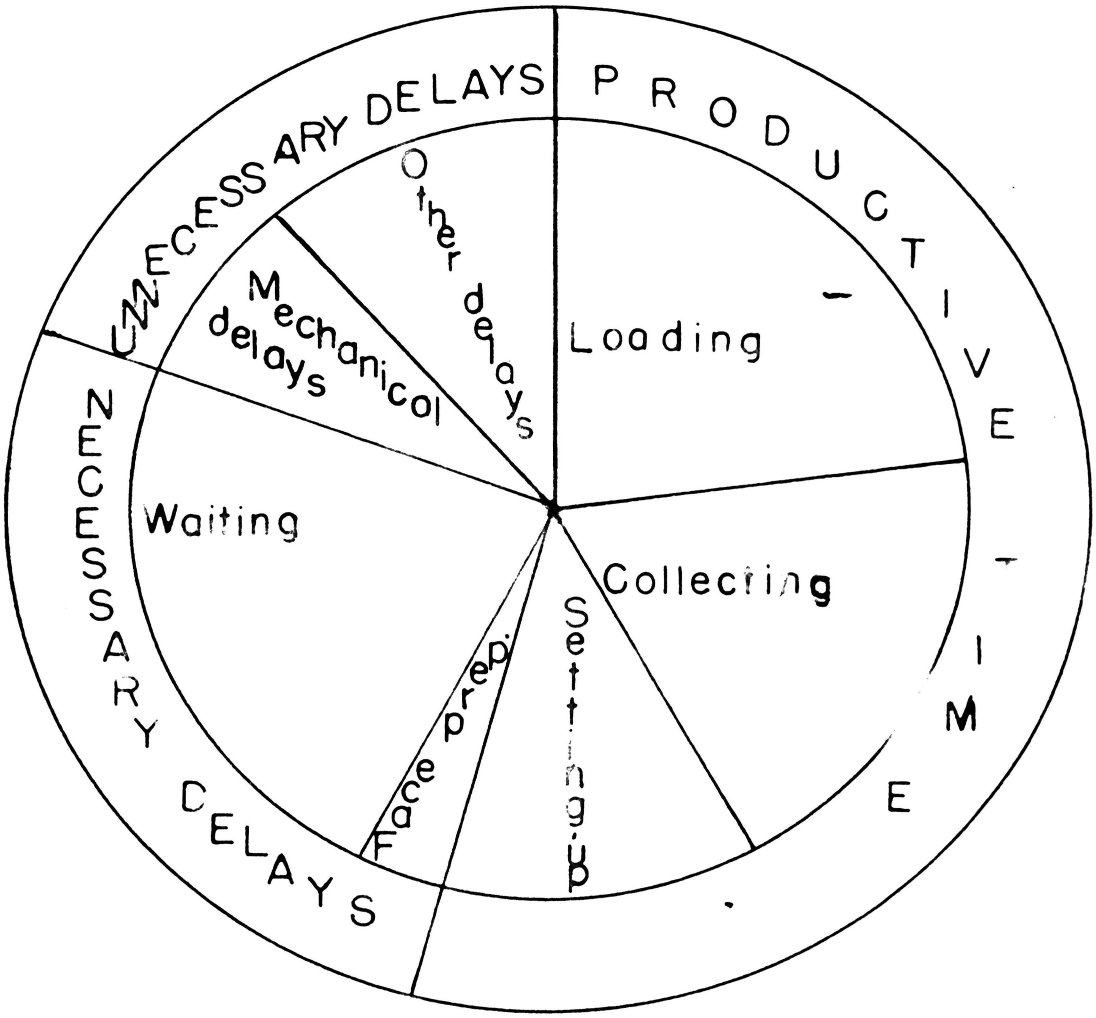


Figure 13. Time Distribution Chart.
Portable Slusher West Gteen Mine.

CHUTE AND SLUSHER OPERATION IN THE FAIRVIEW MINE

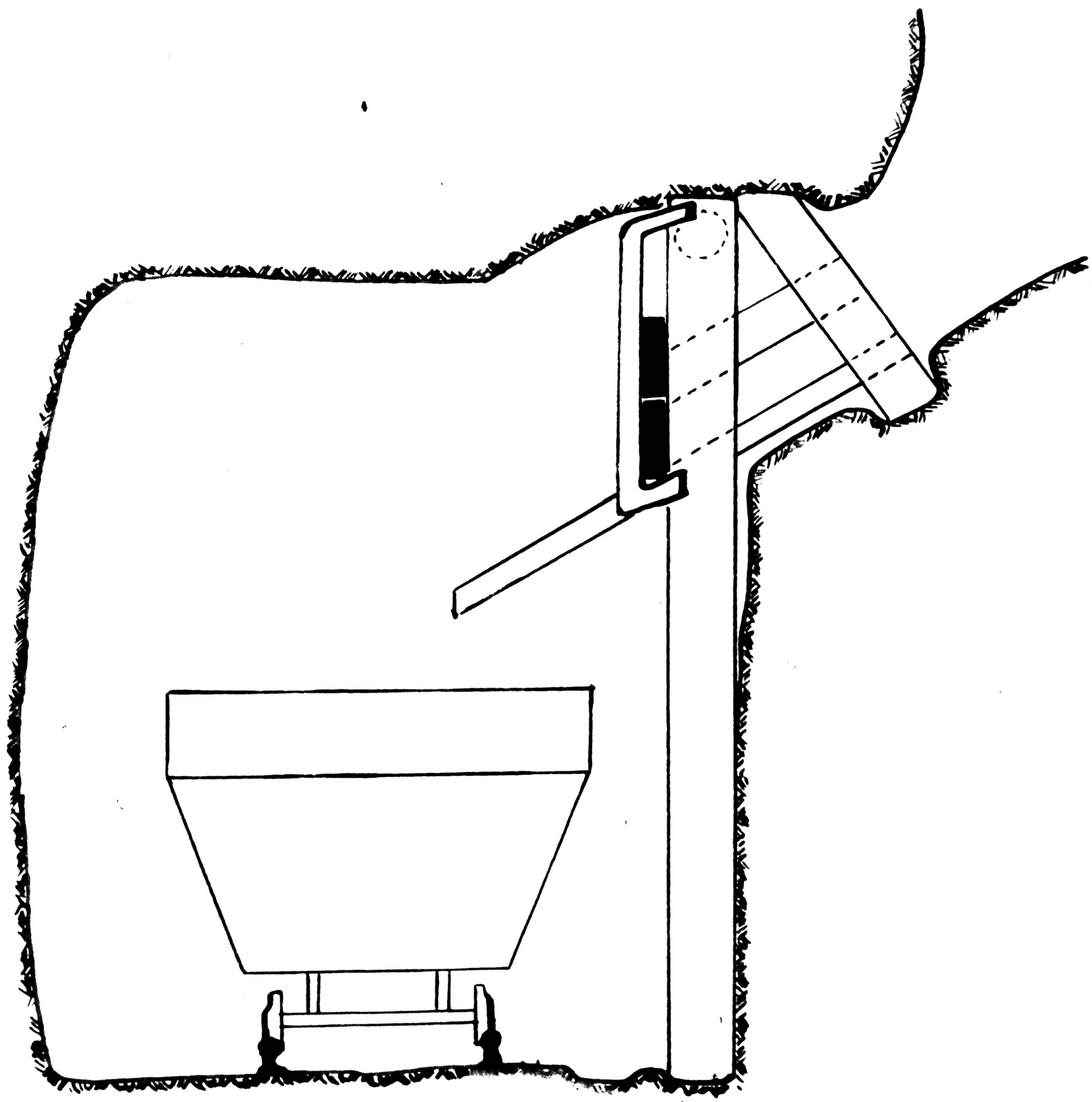
In the Fairview mine, loading is done by means of chutes. The chute loading is considered a part of the haulage operation, and the scraping of the ore in the stopes to the chutes is a separate operation. In the writer's opinion the chute loading and the slusher operation comprise the loading, that is, the transfer of the broken ore from the muck pile to the transportation facilities.

The broken ore in the shrinkage stopes of the Fairview mine can be gravitationally loaded through ore chutes into cars. Two draw holes serve as ore passes from one ore block (see Figure 3). Each draw hole has a wooden guillotine type chute gate (Figure 14) at its bottom end. If the broken ore has a moisture percentage of between 5% and 15%, the ore has a tendency to stick. The clogging of the ore in the gate is frequent. Two men, the motorman and a helper lift the gate to draw the ore. By this method 1 to 2 tons of ore can be loaded per minute.

In the stopes two drum scraper hoists are used to slush the ore into the draw holes. The scraper hoists are powered with 5 HP air motors and the scrapers are 36" in width.

A slusher man and a helper run a scraper hoist. For the foundation of the hoist motor a platform has to be made on the top of the manway (Figure 15). The difficulties in preparing the platform, connecting the compressed air hose, and setting up of the scraper hoist justify the employment of a helper. A slusher's crew is assigned to one or more stopes per day. As the amount of slushed ore per unit of time cannot be measured, it is impossible to evaluate the exact daily performance of the slusher operation. The observation indicates that the major factors controlling the slusher efficiency are the interference of other operations

Figure 14, Guillotine Gate Fairview Mine.



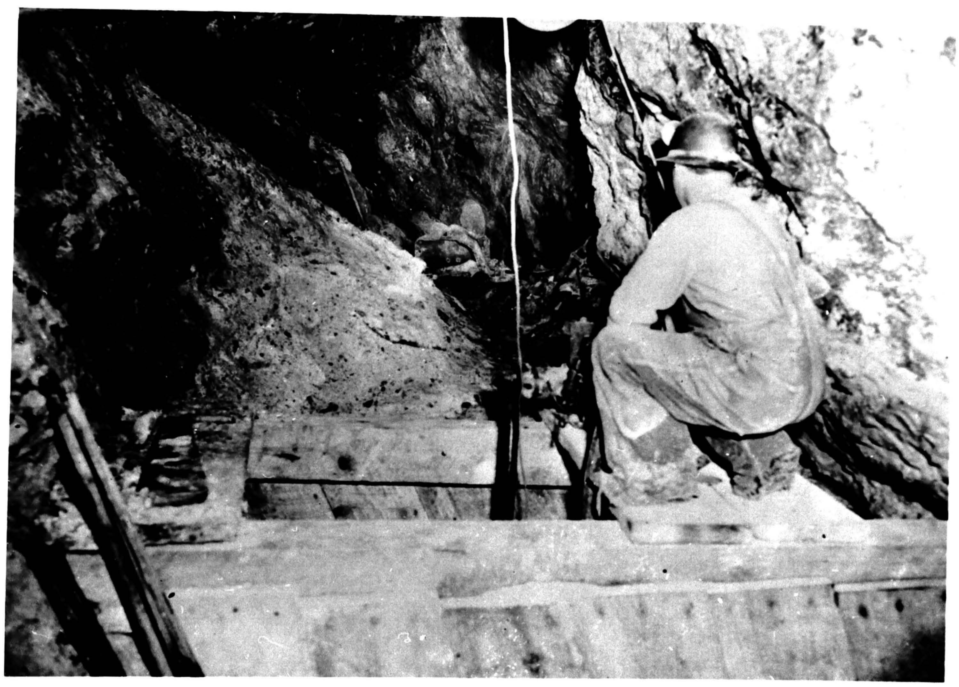


Figure 15. Slusher in the Shrinkage Stope
Fairview Mine. Courtesy of Aluminum Company of America.

(drilling, manway construction, etc), the setting up of the scraper hoist, the curvature and the thickness of the vein.

CONCLUSIONS DRAWN FROM LOADING STUDIES

The major factors leading to the selection of loaders in the flat-bedded mines are the thickness of the ore bed and the availability of skilled operators. The application of both rocker shovel and front end loaders is feasible.

The evaluation of the time studies on portable slushers indicate the following: a. A low number of tons per productive hour for the portable slusher in the West Green Mine shows that it cannot load efficiently into small cans. The percentage of "waiting for other" in the same mine is very high. This is caused by the interference of other operations (mostly of the haulage), which can be reduced by proper distribution of the equipment.

b. The high percentage of mechanical delays is attributed mostly to cable breaks. This can be partly eliminated by preventive maintenance and careful maneuvering of the scraper. The pull rope and the tail ropes have to be regularly inspected, and the bad parts (almost broken) of the ropes have to be cut before they are broken.

c. For small muck piles, the total "setting up" time will increase with the number of muck piles per day, which corresponds to decreasing productivity. This results in that the portable slusher is not a suitable equipment to load muck piles smaller than 60 tons.

d. The other disadvantage of a portable slusher is that one man cannot wholly operate it. The preparation of the anchorage holes interferes with other operations (drilling and maintenance).

To obtain more efficient loading in the Fairview mine, the ore chutes have to be changed to mechanical types that can be opened by one man. Hydraulic guillotine gates or arc type gates which are not expensive are recommended. The improvement in job assignments and the supervision will increase the daily rate of the slushing in the shrinkage stopes.

HAULAGE

The underground haulage systems in the fluorspar mines of southern Illinois all involve short hauls. With the exception of the Crystal Mine the haulage distances never exceed one mile.

From 1948 to 1957 the Minerva Oil Company used a belt conveyor for the main haulage and trucks for the gathering in the southwest stopes of Mine No. 1. During this period the main haulage distance had increased from 500 feet to 1000 feet, and the gathering distances varied from 100 feet to 500 feet. Early in 1957 the company changed the system over to truck haulage from the stopes to the shaft.

As previously mentioned, both truck and track haulage are in use in the mining district. The dip of the flat bedded deposits permits the use of both kinds of transportation. Where the height permits, the trend is to replace the rail haulage system with truck haulage.(12)

---

(12) Montgomery, Robert Gill, Auto Trucks Underground, Mining Congress Journal, Vol. 42, November 1956, pp. 42-44.

In all these mines it is generally true that the haulage operation is the key to production. The underground transportation of the ore is the main and decisive technical factor in the overall daily removal of the ore from the stopes to the surface. However, as will be discussed later, there are special factors in different mines which often determine the daily production.

TRACK HAULAGE

Prior to 1950 rail haulage was the general method of underground transportation of ores in these fluorspar mines. Small battery locomotives with cans or small cars on 20 to 30 inches gauge track was the standard haulage system.

A battery locomotive has the advantage of (1) adaptability to mining openings having low backs, (2) low first cost, (3) ease of operation and maintenance, and (4) greater safety. The main disadvantages are: (1) Not adaptable to rough floor. In some places the ore in the floor has to be left to provide a gradual grade for the tracks. This disadvantage is valid for all types of rail haulage. (2) The gathering performance will decrease by stepping up the progress of the headings. The tracks have to be replaced frequently to follow the headings. (3) It has a low, maximum and average speed. (4) The decreasing capacity of the locomotive during the shift, and the necessity of recharging the battery every day.

At the present time battery locomotive haulage is in use in the following mines:

1. A. L. Davis Mine. In this mine one one-ton battery locomotive serves the mine haulage. It can pull three cans, each of one ton capacity. The railway is a horizontal single track system. The haulage distances range from 300 to 600 feet.

2. Oxford Mine. Two two-ton battery locomotives gather the ores over a distance of 300 to 2500 feet. Each locomotive can pull two loaded cars and each of two-tons capacity. The railway is also a single track system and the maximum grade is 5%.

3. Fairview Mine. Most of the locomotives in this mine are of

two-ton weight. Each locomotive can pull one three-ton loaded Gable-bottom car.

In the 700-foot level larger locomotives of eight ton weight are employed. An eight-ton locomotive can pull a train of 13 to 15 loaded cars each of three-tons capacity on a horizontal track. A single track system is employed and the maximum grade is 1%.

Recently the Ozark Mahoning Company modified two one-ton battery locomotives by substituting diesel powered D.C. generators for the battery in the West Green Mine. Compared to a battery locomotive, the modified locomotive has advantages of the elimination of recharging time and the faster speed. It is expected also that the fuel cost per ton mile will be lower. The two locomotives are used to gather the ore over distances of 300 to 2500 feet. Each locomotive can pull a train of three loaded cans of one-ton capacity. The railway is single track and the maximum grade is 5%.

The West Green Mine was chosen for the object of a more detailed study of the track haulage. Time study was conducted on July 10, 1957 for the track haulage. Each locomotive is run by a motorman.

The transportation cycle is classed into the following subdivisions:

1. Loading (l)

2. Travel-loaded (Tl): the travel time of the loaded train from the loading places to the shaft station.

3. Travel-empty (Te): travel time of the empty train from the shaft station to the loading places.

4. Discharge (D): the time utilized in switching the loaded cans at the shaft station with the empty cans.

5. Maintenance (Me): lubrication and fueling of the locomotive.

6. Handling supplies (Hs): the time spent for handling supplies, explosives, etc; that is, when the train transports the supplies instead of ore.

7. Waiting for others (Wo): the time that the train is hindered from operating by the other operations, such as when the loader is not available, replacement of the tracks, no cans available, etc.

8. Mechanical delays (Dm): all delays caused by the mechanical failures of the locomotives including train derailing.

9. Other delays (Do): all other delays which are not included in mechanical delays, such as when the operator leaves, excessive rest, late starting and early quitting of the shift.

The first 4 subdivisions contribute to the productive use of the locomotive, and the "maintenance," "waiting for others," and "handling supplies" are necessary delays to the progress of the haulage operation. The "mechanical delays" and "other delays" represent the unnecessary delays.

The time observation was made by riding the train, to record the continuous time utilized for each subdivision. Symbols are employed as an aid for faster recording. The summation of time for the subdivisions are then transferred and worked out in a consolidation sheet. The performance rate is shown in Table X and Figure 16 shows the time distribution chart.

TABLE IX

Track Haulage Time Study Consolidation Sheet
West Green Mine

	Time in Min.	%
Te	58.25	12.14
L	104.50	21.77
Tl.	85.25	17.76
D	33.00	6.87
Total Productive Time:	281.00	58.54
Me	27.25	5.67
Hs	13.00	2.70
Wo	54.25	11.71
Total Necessary Delays	96.50	20.08
Dm	31.25	6.51
Do	71.25	14.84
Total unnecessary delays	102.50	21.35
	480	99.97

TABLE X

One Ton Locomotive Performance Rating
West Green Mine

No. of cans in a train: 3

No. trips/shift: 38

Tons/shift: 115

Tons/trip: 3.03

Productive use of the locomotive: 58.54%

Average haulage distance: 325 feet

Average Te/trip: $\frac{58.25}{38} = 1.53$ min.

Average L/trip: $\frac{104.50}{38} = 2.75$ min.

Average Tl/trip: $\frac{85.25}{38} = 2.25$ min.

Average D/trip: $\frac{33}{38} = 0.87$ min.

Average cycle time: 7.40 min.

Mile/Tl hour: $\frac{38 \times 325 \times 60}{5280 \times 85.25} = 1.646$

Mile/Te hour: $\frac{38 \times 325 \times 60}{5280 \times 58.25} = 2.409$

Ton miles/hour (productive time: $\frac{115 \times 325 \times 100}{5280 \times 58.54 \times 8} = 1.512$

Ton miles/hour: $\frac{115 \times 325}{5280 \times 8} = 0.885$

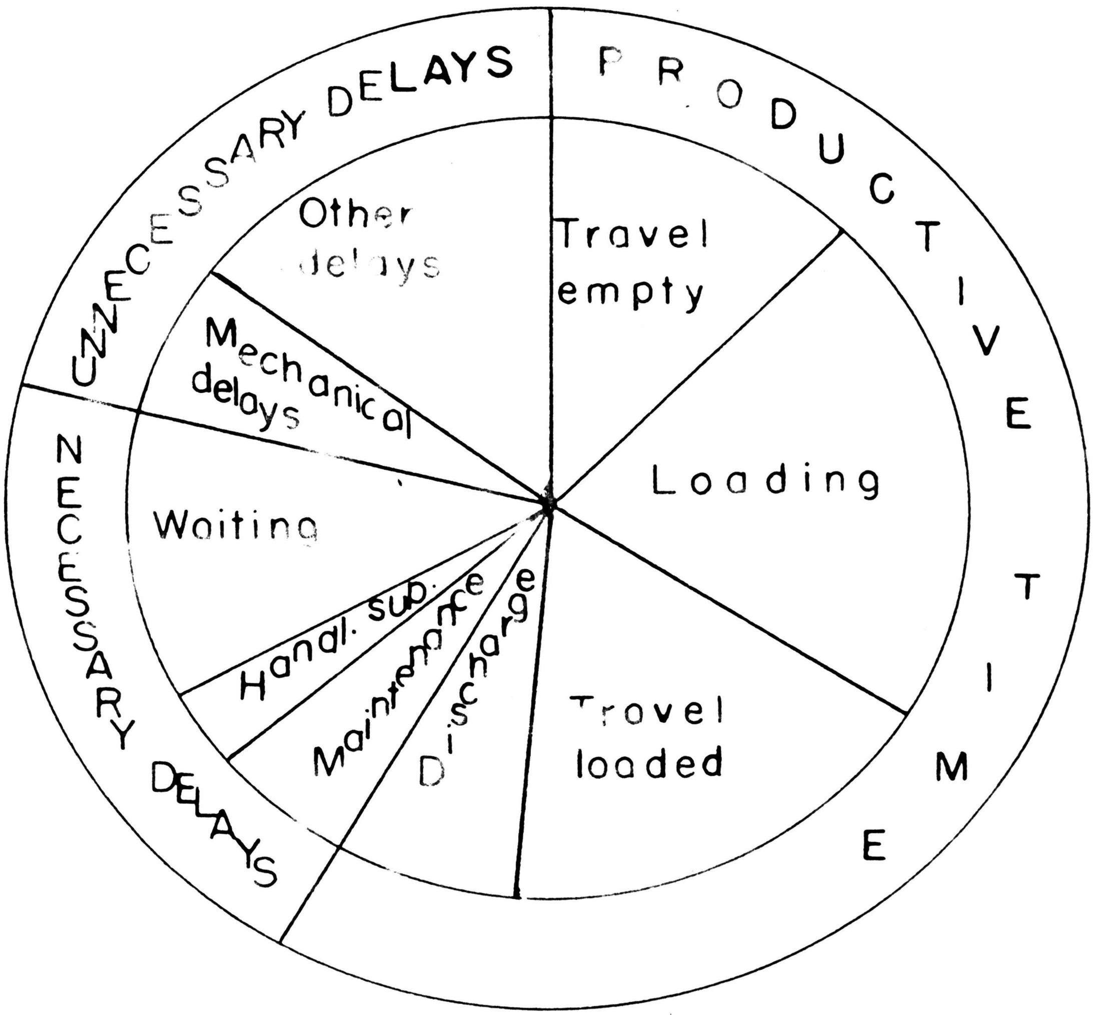


Figure 16. Time Distribution Chart.
Track Haulage West Green Mine.

TRUCK HAULAGE

In 1948 the Minerva Oil Company introduced two electric dump trucks in its Mine no. 1. Each truck was of eight-tons capacity, and each was equipped with a motor operated cable reel. They were used for gathering the ores over distances up to 500 feet from the headings to a hopper which fed the main line conveyor belt. The trucks were slow moving and lacked maneuverability, thus the company was not satisfied with their performance.

In 1950 the Illinois State mining regulations permitted the use of diesel equipment underground. Since then diesel equipment became popular in the underground mines in the district. The toxic gases produced by the diesel engine, that were formerly the main objection to the use of diesel equipment underground, can be kept below the maximum safety limit, by sufficient ventilation, installation of a scrubber in the exhaust of the diesel engine and proper engine maintenance. (13) Late in 1951 the

(13) Allen, V. C., Use of Diesel Equipment in a Zinc-Lead Mine. Mining Congress Journal, Vol. 39, January 1952, pp. 26-49.

Minerva Oil Company replaced the two electric dump trucks with two diesel dump trucks in its Mine no. 1. The company built these two diesel trucks in its machine shop, out of old dump trucks bought from the local used car dealer. The frames of the old trucks were reinforced, the beds were modified, and a 29 HP model DOOD Hercules diesel engine was used to power each truck. By building its own trucks, the company reduced the initial cost, and the modified trucks were hoped to suit the mine conditions better than new standard dump trucks. (14)

(14) Montgomery, Robert Gill, op cit page 45.

To date the Minerva Oil Company uses exclusively self-built diesel dump trucks in its Mine No. 1 and Crystal Mine.

The Ozark Mahoning Company introduced the first diesel truck in its Dealdorf Mine in 1952. (This mine has been worked out.) For a short period in 1953 the company put into trial operation a semi-trailer truck in the same mine. The result was unsuccessful due to the less maneuverability of the semi-trailer truck. To date the company employ truck haulage only in its new opened Hill Mine.

Time studies were conducted for the truck haulage in Mine No. 1. Three diesel dump trucks serve the gathering of the ores from the SW stope. Another truck is used as reserve, and to haul the ores from the pillar extraction somewhere else in the mine. The three trucks are loaded by a portable slusher. In the shaft station the trucks dump the ore into a traveling grizzly which in turn feeds the underground primary Jaw crusher. The layout of the truck haulage way is shown in Figure 2. Figure 17 shows the layout of the discharge station and the standby position near the loading place. The maximum grade of the road is 5%.

The transportation cycle of a truck is more or less similar to the railway haulage. For the study the following job subdivisions are employed:

1. Travel-empty (Te)
2. Loading (L)
3. Travel-loaded (Tl)
4. Discharge (D)
5. Travel (T): The time spent by the drivers to travel from the top of the shaft to get to their trucks and back at the starting and quitting of the shift, and to go to the surface for lunch.

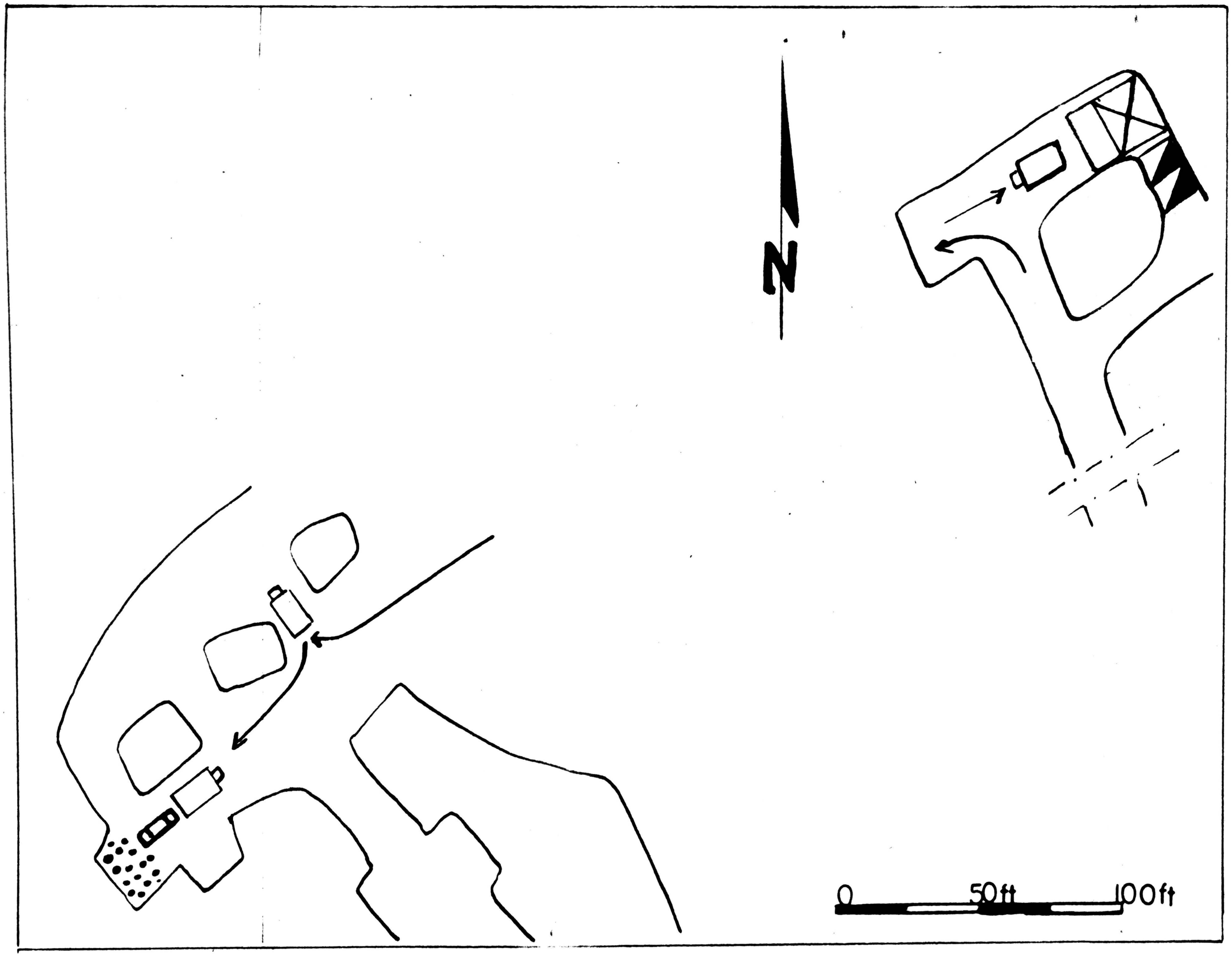


Figure 17. Loading and Discharge Lay-out.
Truck Haulage Mine No. 1.

6. Maintenance (Me): Lubrication, filling the scrubber with water, and filling the diesel fuel tank.

7. Waiting for others (Wo): The time that any of the trucks has to wait for the others to be loaded, and to wait until others finish dis=charging.

8. Handling supplies (Hs): When any of the trucks are used to haul supplies, explosives, etc.

9. Mechanical delays (Dm): All delays caused by the mechanical failures of the trucks such as flat tires, engine failures, etc.

10. Other delays (Do): Operator idleness, late starting or early quitting of the shift, and delay caused by the situation when the underground ore bin has been filled.

The first four subdivisions contribute to the productive use of the trucks, and the "waiting for others," "maintenance," "travel," and "handling supplies" are necessary delays to the haulage operation, while the "mechanical delays" and "other delays" are unnecessary delays.

For the time observation the three trucks were numbered distinctly with Roman numbers (I, II and III). Two men, one at the shaft station and one at the loader, recorded the activities of the trucks with symbol system in working sheets. Both men used regular wrist watch for the timing. Before and after the timing the two watches were checked for synchronization. The field working sheets are then worked out and transferred to the consolidation sheets. Table No. 12 shows the performance rating of the trucks, and Figure 18 shows the average time distribution chart.

TABLE XI
Time Study Consolidation Sheet
Truck Haulage Mine No. 1

Subdivision	Truck No. 1		Truck No. 2		Truck No. 3		Average	
	Min.	%	Min.	%	Min.	%	Min.	%
Te	62.25	12.96	62.25	12.96	53.25	11.10	59.25	12.34
L	56.75	11.82	57.50	11.97	65.75	13.71	60.00	12.50
Tl	56.75	11.82	57.75	12.03	52.75	11.00	55.75	11.61
D	7.25	1.51	7.75	1.61	7.75	1.61	7.58	1.58
Total Productive Time	183.00	38.11	185.25	38.57	179.50	37.42	182.58	38.03
Me	36.00	7.50	35.00	7.29	34.00	7.09	35.00	7.29
T	91.75	19.11	53.75	11.20	54.75	11.42	66.75	13.91
Wo	76.25	15.89	94.50	19.69	49.75	10.38	73.50	15.32
Hs*	---	---	---	---	---	---	---	---
Total Necessary Delays	204.00	42.50	183.25	38.18	138.50	28.89	175.25	36.52
Dm	53.25	11.09	79.75	16.61	145.75	30.40	92.92	19.36
Ds	39.75	8.28	31.75	6.61	15.75	3.28	29.08	25.42
Total Unnecessary Delays	93.00	19.37	111.50	23.22	101.50	33.68	122.00	25.42
Total	480.00	99.98	480.00	99.97	479.50	99.99	479.83	99.97

* The reserve truck was used for hauling supplies at the period of study.

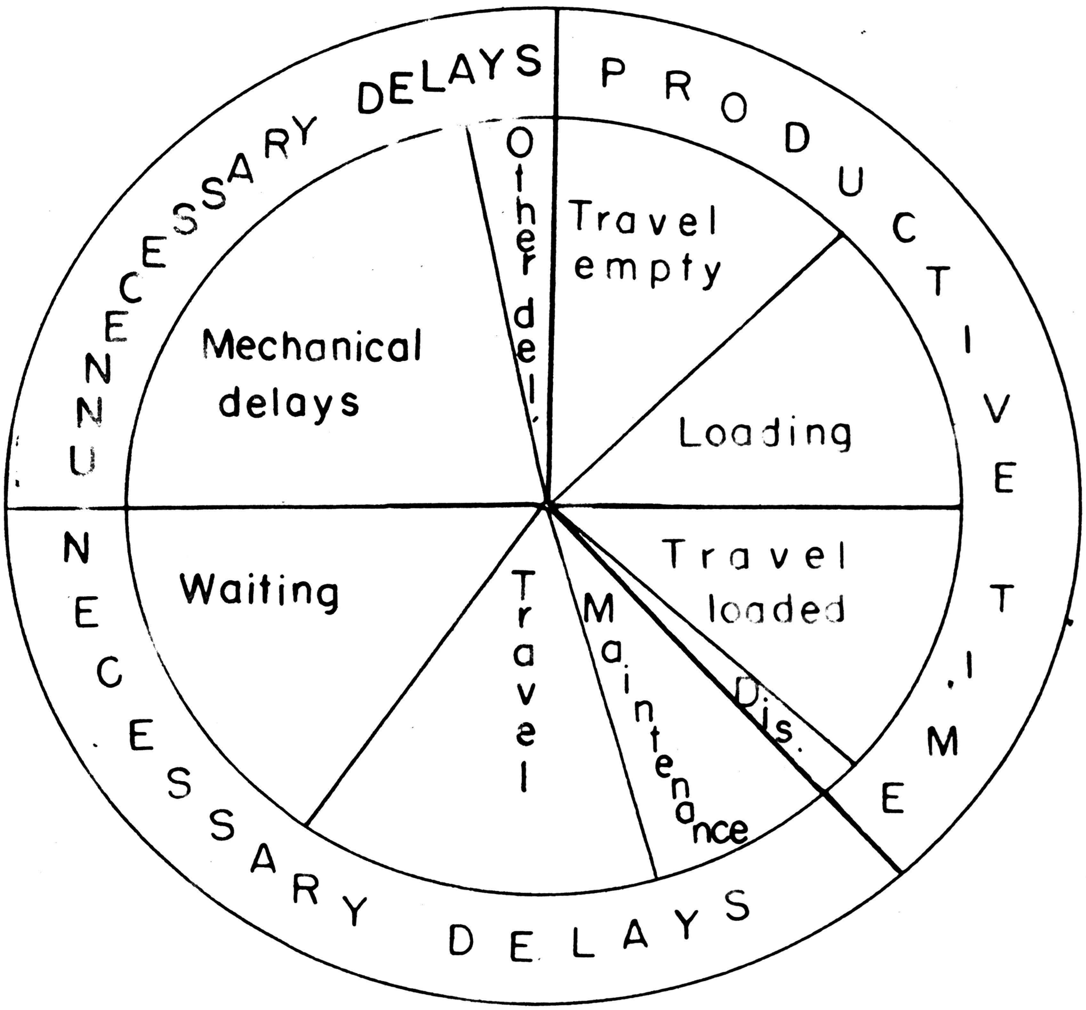


Figure 18. Average Time Distribution Chart.
Truck Haulage Mine No. 1.

TABLE XII
Truck Haulage Mine No. 1
Performance Rating

	Truck No. 1	Truck No. 2	Truck No. 3	Average
No. of Trips Per Shift	17	19	18	18.
Ton per shift	88.4*	98.8*	93.6*	93.6
Ton per truck	5.2	5.2	5.2	5.2
Productive Use of truck	38.11	38.57	37.42	38.03
Average Loading Time Per Trip	$\frac{56.75}{17} = 3.34$	$\frac{57.50}{19} = 3.03$	$\frac{65.75}{18} = 3.65$	3.34
Average Tl time Per Trip	$\frac{56.75}{17} = 3.34$	$\frac{57.75}{19} = 3.04$	$\frac{52.75}{18} = 2.93$	3.10
Average Te Time Per Trip	$\frac{62.25}{17} = 3.66$	$\frac{62.25}{19} = 3.28$	$\frac{53.25}{18} = 2.96$	3.30
Average D Time Per Trip	$\frac{7.25}{17} = 0.43$	$\frac{7.75}{19} = 0.41$	$\frac{7.75}{18} = 0.43$	0.42
Average Te=Tl	2176 ft.	2176 ft.	2176 ft.	
Average miles/tl Hour	$\frac{2176 \times 17 \times 60}{56.75 \times 5280} = 7.407$	8.135	8.438	7.993

TABLE XII, Continued

	Truck No. 1	Truck No. 2	Truck No. 3	Average
Average Miles/Te Hour	$\frac{2176 \times 17 \times 60}{62.25 \times 5280} = 6753$	7.547	8.358	7.553
Tons Miles Per Hour (Productive Time)	$\frac{100}{38.11} \text{ X } \frac{2176 \times 88.4}{8 \times 5280} = 11.947$	13.194	12.888	12.675
Ton Miles Per Hour	$\frac{2176 \times 88.4}{8 \times 5280} = 4.553$	5.089	4.821	4.821

*The trucks are assumed to have the same capacity.

TRUCK HAULAGE IN THE CRYSTAL MINE

In the Crystal Mine which is an adit mine, Minerva Oil Company uses the same type diesel dump trucks as in the Mine No. 1. The trucks haul the ores from the stopes to the mill over distances up to 1.25 miles. The dip and the thickness of the ore bed provide a good condition for the truck haulage.

The mine consists of three separate properties which were developed and mined by different property owners with poorly planned small-scale operations. The Minerva Oil Company bought the Crystal property in 1952, and leased the other two properties in 1955. At the present time the producing west stopes are nearing the boundary of the property. The haulage road passes through the old workings following many curves and steep (up to 15%) slopes. The haulage road is not well maintained. This road condition and the fact that the company uses only second hand trucks results in many mechanical breakdowns. These road and truck conditions are the prevalent factors contributing to the low efficiency of the truck haulage in this mine.

CONCLUSIONS OF THE HAULAGE STUDIES

The time studies and the performance rating of the rail haulage show the low number of ton miles per hour, and the low traveling speed per hour (Tl and Te miles per hour), which correspond to the low capacity of the locomotive haulage. The low traveling speed is partly caused by the grades of the railways. The high percentage of "waiting for others" indicates the frequent interference of other operations, particularly of the hoisting. This can be partly eliminated by harmonization of the capacity of the equipment used in each stage of the production, and proper distribution of the equipment. The high percentage of "other delays" could be reduced with close and able supervision.

The time studies on the truck haulage shows the low productive use of the trucks. The amount of "waiting for others" time can be eliminated by proper distribution of the trucks. The "travel" time, if possible, should be eliminated from the transportation cycle. The high percentage of mechanical delays can be partly eliminated by proper maintenance of the trucks and the road. These steps will increase the productivity of the trucks.

The proportion of average "loading," "travel-loaded" and "travel-empty" times indicates that the capacity of the loader and the 3 trucks at this particular haulage distance is about equal, which is an important factor in the overall effective use of the loader and the trucks.

Compared to the locomotive haulage, each truck has more capacity, speed and mobility.

SHIFT PRODUCTIVITY

In most of the underground mines, the three major operations discussed in the preceding chapters (drilling, loading and haulage) are the main factors contributing to the overall shift productivity. In relatively small mines, the effect of maintenance, support, hoisting, and supervision on the production is more appreciable. These and other factors peculiar to a certain mine will be summarized in the following paragraphs.

In Mine No. 1, the final target of the underground production is the maximum mill capacity of 325 tons per 24 hours. Since underground loading and haulage proceed only during the day shift, 6 days a week, two ore bins with a total capacity of 370 tons are added to the mill to provide the ore storage for the mill feed during the night and on Sunday. At any time that both bins have been filled during the day shift, the underground haulage and loading must cease. This causes an appreciable amount of unnecessary delay in this mine.

The can hoisting in the West Green and A. L. Davis mines is very slow. It affects the underground haulage by the delay to wait for the empty cans. A crew of four men operate the can hoisting in each mine, one hoist man, one switch man at the shaft station, and two grizzly men at the top. This large number of hoisting crew members decreases the productivity of the shift. The cage hoisting in the Oxford mine has the same effect as the can hoisting (see Table XII).

In the Fairview mine, the large number of employees in the roof support crew contributes to the low number of tons per man shift. The critical mining drainage problem, which is due to tremendous amounts of water in the 700 level believed to flow from the Ohio River, requires more mechanics for pump maintenance.

It is conventional to indicate the shift productivity in terms of tons per manshift.

Table No. XIII shows the shift productivity for the month of June 1957.

Higher number of tons per manshift in these mines does not necessarily indicate higher efficiency. There are differences in the shift reporting system of the companies. In the Ozark Mahoning mines the number of maintenance employees (support, mechanics, and electricians) is arbitrarily assigned to each mine every day. In the Minerva Oil Company and Alcoa mines, a more accurate time keeping system is employed.

Table XIV shows the production cost per ton of ore in the flat bedded mines, while Table XV shows the production cost in the Fairview vein mine. Some of these figures, for example the cost of drilling, contradict the argument presented in the previous discussion. From the discussion on the drilling it can be assumed that the cost of breaking in the Ozark Mahoning Mines should be lower than in the Minerva mines. The accounting system of the two companies differ in (1) the assignment of distributable accounts, (2) distribution of the supply account to the production cost and (3) the assignment of secondary prospecting account (underground diamond drilling and surface drilling for determination of the trend of the ore body). By full understanding of the account system of the companies one can better evaluate the effects of the shift producticity to the production cost. The ratio of the cost of labor compared to the cost of supplies for the breaking, loading and haulage in the flat bedded mines is estimated to be 5 to 3.

TABLE XIII

Shift Productivity

No. of man shift per day

MINE

	Drilling	Loading	Haulage	Hoisting	Support	Foreman Shift-bosses Mechanics	Total	Average Production PerDay	Tons Per Man Shift
Oxford	4	4	2	4	2	4	20	163	8.15
A.L.Davis	2	1	1	4	-	1	9	72.5	8.00
West Green	2	2	2	4	-	3	13	121	9.4
Hill	2	2	1	1		1	7	89	12.7
Mine No. 1	11.4	7.2	7	4	6.5	6	42.1	326	7.7
Crystal	13	5.2	21.3	1.9	2	5.3	48.7	546	11.2
Fairview	29	19	13	9	34	25	129	334	2.6

TABLE XIVj

Cost of Production Per Ton of Ore

	Breaking	Loading	Haulage	Hoisting	Timbering	Pumping and Power	Boulder Breaking at the Mine	Super-vision & Overhead	Total
Mine No. 1	.84	.25	.46	.17	.27	.21		.53	2.73
Crystal	.86	.34	.96	.13	.20	.19		.24	2.92
West Green	.58	.51	.22	.27	.65	.36	.22	.87	3.68
Oxford	1.18	.57	.10	.42	.30	.39	.16	1.14	4.26
A.L.Davis	1.31	.67	.24	.48	.60	.33	.18	1.07	4.88
Hill	.73	.18	.03	.37	.53	.65		1.48	3.97

TABLE XV

Production Cost Fairview Mine

		Labor Cost/Ton	Supply Cost/Ton	Total
1.	Crosscutting	.06	.06	.12
2.	Drifting	.29	.18	.47
3.	Raising	.27	.17	.44
4.	Breaking	2.24	1.51	3.75
5.	Drawing (slushing)	1.02	.34	1.36
6.	Tramming	1.36	.45	1.81
7.	Hoisting	.49	.16	.65
8.	Mine Ventilation & Drainage	.31	2.21	2.52
9.	Compressed Air, Electricity	.18	.07	.25
10.	General service	.24	.36	.60
11.	Indirect		2.16	2.16
	Total	6.36	7.67	14.03

CONCLUSIONS

Flat Bedded Mines

In these relatively small mines the method of development of a mine plays a more important factor in the present mechanization of the particular mine. A development method that can facilitate a flexible daily output should be considered in the planning of a mine. The design of the hoisting and supplementary facilities (switching station, grizzly, etc.) should be made so as not to interfere with the underground operation. For a mine with a daily production of more than 150 tons, one-ton can hoisting is not recommended.

To eliminate the dependence of the underground operation on the mill capacity, a provision for stockpiling of the ores near the mill can be made.

. The lay-out of a mine is an important factor for the efficiency of all underground operations. Better layout will have the effects of more concentrated operation, less interference of the equipment with other equipment, more safety, and easy inspection. In the truck haulage mines, a systematic diagonal layout of the safety pillars (instead of the irregular pillars) is recommended (Figure 19). With a diagonal layout, smoother turns for the haulage road can also be obtained. In the track haulage mines regular and perpendicular layout of the safety pillars is more advantageous.

The most practicable step to mechanize the present mines is to increase the efficiency of all stages of underground operations. Referring the the previous conclusions of the drilling, loading and haulage, all necessary steps to increase the productivity of the three operations have been outlined. In general by stepping up the productive use of the drilling, loading and transportation equipment to 75%, the daily production will be doubled.

The harmonization of the capacity of the drilling, loading and haulage operations is often neglected in these mines. The idleness and misuse of the equipment are frequently the result of the poorly proportioned capacity of the equipment in each stage of operation. As the daily capacity of the haulage units decreases with the increasing haulage distance, the haulage operation can be taken as the key in the harmonization of the capacity of the three operations.

Comparing the equipment in the flat bedded mines, the jumbo for the drilling, portable slusher for the loading and trucks for the haulage as employed in the Mine No. 1 represent the most mechanized operation. If the remaining ore reserve in a certain mine warrants, the change of the old mining method to a more mechanized mining method should be considered. In particular, the track haulage mine can be changed to a truck haulage mine, and the airleg drills can be replaced by jumbo drills. Continuous education of the equipment operators by able supervisors is a main contributing factor to the success of the application of more-mechanized equipment.

Fairview Mine

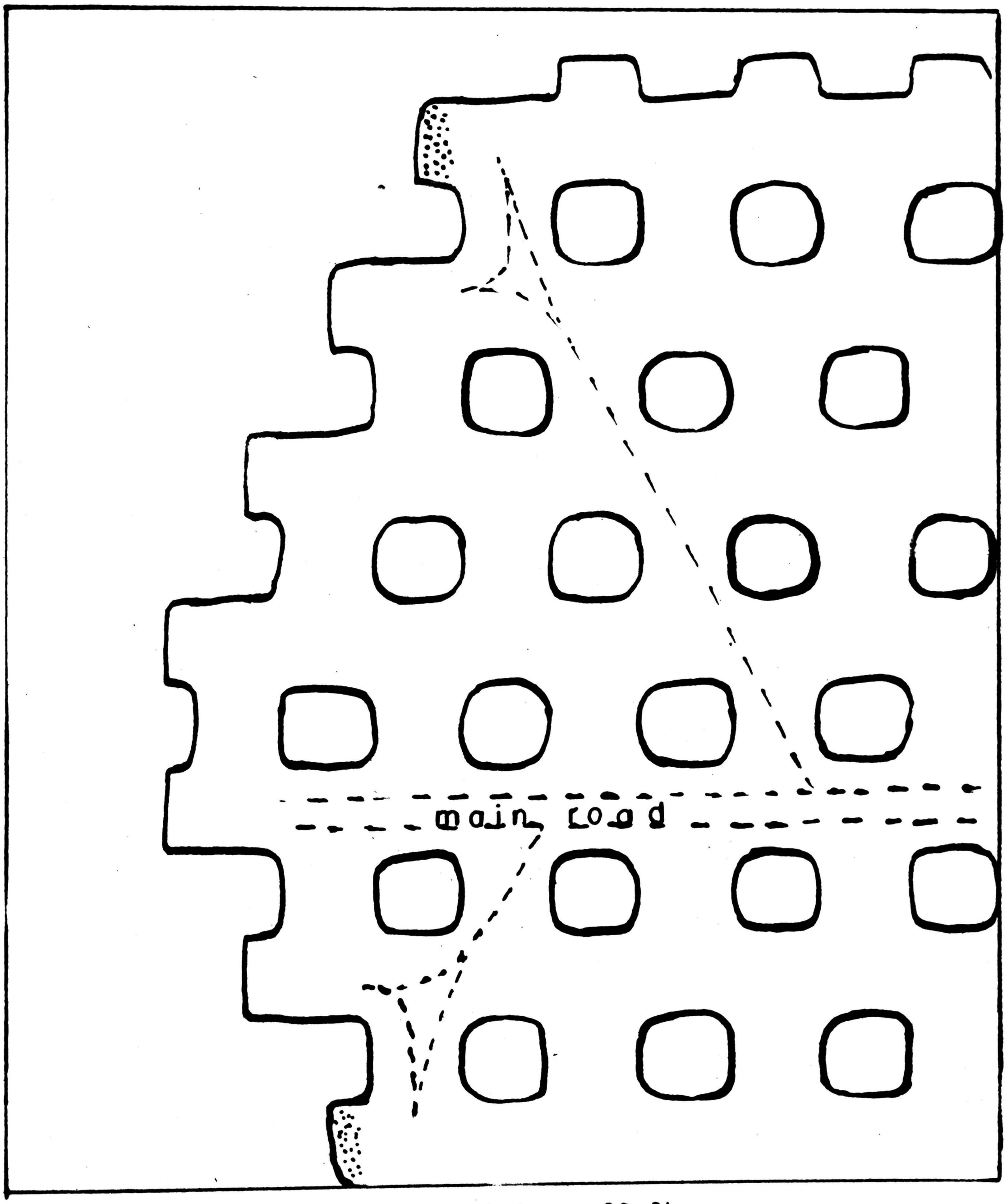
In the drilling operation in the Fairview mine, an incentive wage system is expected to increase the drilling rate with the stoper drills in the stopes. A standard footage per day under special conditions derived from the average daily drilling performance can be taken as a standard for the incentive wage system.

The rate of the ore slushing in the stopes cannot be measured daily. Able supervision and better assignment of the daily work to the slusher operators will increase the slushing performance. The neighboring stopes should be planned to progress at the same time so that two neighboring stopes can be slushed from a single position of the slusher. More efficient ore chutes have been suggested in the previous conclusions on the loading operation.

The improvement of haulage conditions in this mine is a problem typical of that involved in other mines which employ permanent track haulage. With a larger capacity of the locomotives, more tons of ore can be hauled per trip. The possibility of the use of other types of locomotives should be investigated. Better maintenance and lay-out of the tracks will increase the haulage efficiency.

In this vein mine there are more interferences of support and maintenance with other operations. The interferences can be greatly reduced with better planning and coordination of the daily underground activities. Being entirely different from the flat bedded mining operations, there is no way to compare the mechanization problems in this mine to the flat bedded mines.

Figure 19, Proposed Pillars Diagonal Layout For a Truck Haulage Mine, 75-80% Extraction.



Scale: 1 in. = 80 ft.

SUMMARY

The Southern Illinois fluorspar mines pose problems of mining mechanization peculiar to small or medium size mining operations in many districts. Two different mining methods, the open stope room and pillar method for the flat bedded deposits, and slusher type shrinkage stoping for the vein deposits, are applied in the district. Various types of equipment are used in the underground operations. The three major underground processes, the drilling, the loading, and the haulage were first analyzed to reveal the prevalent technical and economical considerations in applying the present mining practice. Motion study and time study procedures for the drilling, loading, and haulage operations were formulated. Time and motion studies were conducted in selected mines to obtain detailed data of the efficiency and performance ratings of the employed equipment. These studies reveal that in many cases the present practices can be improved by better education of the equipment operators, proper selection and maintenance of the equipment, better layout of the mines and better coordination of the underground processes. Conclusions were made which present ideas to further mechanization of the mines, improvement of the operation efficiency and stepping up of the overall shift productivity.

BIBLIOGRAPHY

I. Books:

Carroll, Phil. Jr., Time Study For Cost Control; McGraw Hill Book Co. 1943.

Alford, L. P., Principles of Industrial Management. The Ronald Press Company 1944.

Maynard, L. and Stegemerten, Time and Motion Study, McGraw Hill Book Co. 1940.

Peele, R., Mining Engineer's Handbook, Vol. I and II.

II. Periodicals:

Allen, V. C., Use of Diesel Equipment in a Zinc-Lead Mine, M.C.J. Vol. 39, Jan. 1953, pp. 26-49.

Anderson, O. E., How Minerva Oil Company Produces High Grade Ceramic Fluorspar, E.M.J., Vol. 194, No. 3, March 1953, pp. 72-78.

Clark, G. B., and Harrison, W. H., Jr., Slusher Solves the Shrinkage Problem, E.M.J., Vol. 149, May 1948, pp. 80-81.

Harley, G. T., Time Study Methods for Mining Operations, E.M.J., Vol. 123, 1927, pp. 722-729.

Montgomery, R. G., Auto Trucks Underground Mining Congress Journal, Vol. 42, November 1956, pp. 42-44.

III. U. S. Government Publications:

Needham, A. B., Methods and Costs of Mining Fluorspar From Flat-Bedded Deposit at Cave in Rock, Bureau of Mines Information Circular No. 7514, 1949, 10 p.

IV. State Publications:

Forrester, J. D. and Fuller, J. A., An Analysis of Man-power Efficiency in Drilling Procedures in Tri-State Mining District, Missouri School of Mines and Metallurgy Bulletin, Vol. 17, No. 1, 1946, 54 p.

Forrester, J. D. and Clayton, A. B., A Study of Mine Scraper Buckets and Their Efficiency, Missouri School of Mines and Metallurgy Bulletin, Vol. 17, No. 2, 1947, 48 p.

Mineral Industries Experiment Pennsylvania State College. More Profit in Mechanical Mining Through Studies of Loading and Gathering Performance, Bulletin No. 50, 1947, 37 p.

Weller, J. M., Grogan, R. M., and Tippie F. E., Geology of the Fluorspar Deposits of Illinois. Illinois State Geological Survey Bulletin No. 76, 1952, 147 p.

V. Unpublished Materials:

Montgomery, R. G., Adaptation of Diesel Rubber-Tired Loading Equipment to a Bedded Fluorspar Mine. Thesis for Engineer of Mines Degree at the Missouri School of Mines and Metallurgy, T.1046, 1953, 33p.

Wheelock, L. K., An Efficiency Analysis of Underground Haulage in the Tri State Mining District, Thesis for Master Degree at the Missouri School of Mines and Metallurgy, T. No. 999, 1952, 192 p.

VITA

Marangin Simatupang, son of Mr. and Mrs. St. Friedrick Simatupang, was born in Pangaribuan, Tarutung, Indonesia on July 4, 1930.

His elementary education was completed at the Zending's Vervolg School, Pangaribuan, Tarutung, Indonesia in 1941. His secondary education was interrupted from 1945 to 1949. During this period he served with the Indonesian Army and was discharged as a second lieutenant at the end of 1949. He entered the State Senior High School at Djakarta, Indonesia in 1950 and graduated in 1952.

In August 1952 he enrolled in the Mining Department, Institute of Technology, University of Indonesia at Bandung, Indonesia and received his Bachelor of Science degree in Mining Engineering in September 1956.

He came to the United States at the end of 1956 under the Technical Exchange Program of the International Cooperation Administration. He was admitted as a graduate student at the Missouri School of Mines and Metallurgy in February 1957.